Kalispel Resident Fish Project

Annual Report
2003 - 2004

DOE/BP-00004574-2

April 2004

This Document should be cited as follows:

Olson, Jason, Todd Andersen, "Kalispel Resident Fish Project", 2003-2004 Annual Report, Project No. 199500100, 97 electronic pages, (BPA Report DOE/BP-00004574-2)

Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

KALISPEL RESIDENT FISH PROJECT

ANNUAL REPORT

2003

PREPARED BY:

JASON OLSON AND TODD ANDERSEN
KALISPEL NATURAL RESOURCE DEPARTMENT

PREPARED FOR:

U.S. DEPARTMENT OF ENERGY
BONNEVILLE POWER ADMINISTRATION,
DIVISION OF FISH AND WILDLIFE

P.O. BOX 3621
PORTLAND, OREGON
97208-3621

PROJECT NUMBER 1995-001-00

CONTRACT NUMBER 00004574

Executive Summary

In 2003 the Kalispel Natural Resource Department (KNRD) continued monitoring enhancement projects (implemented from 1996 to 1998) for bull trout (*Salvelinus confluentus*), westslope cutthroat (*Oncorhynchus clarki lewisi*) and largemouth bass (*Micropterus salmoides*). Additional baseline fish population and habitat assessments were conducted, in 2003, in tributaries to the Pend Oreille River. Further habitat and fish population enhancement projects were also implemented.

Acknowledgments

We would like to thank Glen Nenema (Chairman, Kalispel Tribal Council), the Kalispel Tribal Council and members of the Tribe for providing the support and the opportunity to conduct this project. Special thanks goes to Joe Maroney (KNRD Fisheries Program Manager) for technical and administrative support and assistance. The U.S. Department of Energy, Bonneville Power Administration, provided financial support for this project, contract number 00004572. Special thanks also to Ron Morinaka (Contracting Officer Technical Representative). The Kalispel Natural Resource Department provided field support and equipment.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

Fire history, past timber harvest activities, and dams have influenced the landscape in the Lower Pend Oreille Subbasin. The subbasin was first logged from 1915 to 1930 and much of the old-growth timber was removed. Logging railroad and log flumes were used on the mainstem Pend Oreille River and several of its tributaries. Log flumes were common, simplified the instream habitat, and decreased the recruitment source of large woody debris. In more recent years, road construction and maintenance, timber harvest, and cattle grazing have degraded stream habitat conditions. Numerous forest fires occurred between 1910 and 1929 and impacted many watersheds. From 1917 to 1929, an estimated 60 to 70% of the LeClerc Creek watershed burned. The largest fire in the LeClerc Creek watershed occurred in 1929.

The fish assemblage existing today in the subbasin is drastically different from pre-dam development. Due to the construction of Grand Coulee Dam, anadromous fish have been extirpated and over 1,140 linear miles of spawning and rearing habitat in the Upper Columbia River System were eliminated (Scholz et al. 1985). The five dams on the lower Pend Oreille River are also believed to be a significant reason for the decline of native salmonid populations. These dams include Waneta (Canada), Seven Mile (Canada), Boundary (U.S.), Box Canyon (U.S.), and Albeni Falls (U.S.). None of these dams were built with fish passage facilities. Other dams and diversions such as Cedar Creek Dam, Sullivan Lake Dam, Mill Pond Dam, North Fork Sullivan Creek Dam, and Calispell Pumps were constructed in Pend Oreille River tributaries and further fragmented the connectivity of native salmonid populations.

In an attempt to partially mitigate for the resident and anadromous fish losses caused by hydropower development and operation, the Northwest Power Planning Council (Council) called for recommendations to develop a program that would provide measures to protect, mitigate and enhance fish and wildlife affected by the construction and operation of hydroelectric facilities located on the Columbia River and its tributaries. The Tribe, in conjunction with the Upper Columbia United Tribes (UCUT) Fisheries Center, undertook a three-year assessment of the fishery opportunities in the Pend Oreille River (Ashe et al. 1991) to provide the Council with recommendations. Assessment findings indicated that trout species were rare in the reservoir and compose less than 1% of the total abundance. Brown trout (*Salmo trutta*) were the most abundant trout species. Factors limiting trout production in the reservoir were identified as warm water temperatures, lack of habitat diversity and food availability. Trout were more abundant in the tributaries to the reservoir, which mostly supports brook trout (*Salvelinus fontinalis*) and brown trout; however, westslope cutthroat (*Oncorhynchus clarki lewisi*), rainbow (*O. mykiss*), and bull trout (*S. confluentus*) were also captured.

Ashe et al. (1991) also found that largemouth bass (*Micropterus salmoides*) comprised approximately 3-4 percent of the total fish population in the reservoir. Results indicate that growth rates of largemouth bass during the first four years in the Box Canyon Reservoir were lower than bass from other locations of the northern United States. The slower growth rates combined with a high rate of juvenile mortality associated with lack of overwintering habitat have reduced the potential for the bass population in the reservoir.

Bennett and Liter (1991) described the fish communities in Box Canyon Reservoir, the sloughs, and tributaries and examined factors that could limit game fish production. Their findings determined that factors such as warm water temperatures and thermal barriers at the mouths of sloughs limited native trout. They estimated that overwinter survival of age 0^+ largemouth bass in Box Canyon Reservoir ranged from 0.4-3.9%. It was suspected that poor overwinter survival is partially due to the lack of cover during the winter months.

Ashe et al. (1991) provided recommendations based upon these findings for enhancing fishery opportunities. Recommendations include: 1) construct an off-site rearing facility to supplement the number of juvenile largemouth bass within the Box Canyon Reservoir; 2) enhance tributary populations of native trout, and; 3) increase the amount of overwinter habitat in the reservoir. Bennett and Liter (1991) suggested similar management possibilities in the Box Canyon Reservoir such as supplementation of largemouth bass to enhance recruitment and introduction of a predator species to take advantage of the extensive forage base.

The recommendations from Ashe et al. (1991) were adopted and incorporated into the 1994 resident fish and wildlife section of the Council's Program and were further revised in the Council's 1995 Program. These recommendations called for:

1) Restoring tributary populations of native cutthroat and bull trout, and

2) Enhancing the largemouth bass population to provide a quality sport and subsistence fishery in the reservoir.

These goals may appear to conflict, but there is a dramatic difference in habitat between the tributaries and Box Canyon Reservoir. The Box Canyon reach of the Pend Oreille River was formed in 1955 by the construction of Box Canyon Dam. The dam changed the riverine habitat in this reach to habitat typical of a broad, shallow reservoir. The resulting high summer water temperatures exceeded Washington Department of Ecology temperature standards on a regular basis. This change in habitat made favorable conditions for warmwater species. Ashe et al. (1991) and Bennett and Liter (1991) concluded that yellow perch is the most abundant species in Box Canyon Reservoir. The other species in descending order based on relative abundance are pumpkinseed, tench, and largemouth bass. Trout species are rare and of the trout species present, brown trout are the most abundant. Tributary trapping data suggests that brown trout is the only trout species in Box Canyon Reservoir having an adfluvial population (KNRD et al. 2001). Temperature conditions limit the distribution of native trout in the reservoir. Bull trout have optimal rearing temperatures of 7-8^{0}C (Goetz, 1989) and temperatures exceeding 15^{0}C are thought to limit distribution (Fraley and Shepard, 1989, Goetz, 1991, Pratt, 1985). In Box Canyon reservoir, bull trout are limited to microhabitats in cold water springs, or metalimnion areas. Bull trout require spawning areas with clean gravel and temperatures ranging from 5-9^{0}C; these conditions do not exist in the reservoir. Conversely, largemouth bass have optimum temperatures of 13-26^{0}C and will select habitats in the littoral zone where temperatures exceed the optimum for bull trout. Thus, habitat overlap between native trout and largemouth bass is unlikely and interaction very unlikely (NEPA Doc, 1996).

Cutthroat and bull trout populations residing in the tributaries need to be protected since these appear to be the remaining populations in the Lower Pend Oreille Subbasin. The greatest impacts to these populations include: 1) habitat degradation from past land use activities; 2) habitat fragmentation and loss of connectivity due to man made structures; and 3) hybridization and competition from introduced species. Genetic analysis conducted by the Washington Department of Fish and Wildlife (WDFW) showed that Pend Oreille River tributary populations of westslope cutthroat trout were genetically distinct from one another (Shaklee and Young 2000). Of the eight tributaries surveyed in the initial year of the project, none have been stocked with hatchery fish since 1978. Four of the eight have not been stocked since the 1940's. Although relative abundance is low, genetic analysis and stocking records suggest these cutthroat trout populations are sustained without hatchery supplementation.

Isolation due to the fragmentation of native populations is likely to increase the risk of extinction through both environmental stochasticity and lack of genetic variation (Rieman and McIntyre 1993; Lacy 1987). Degraded habitat resulting in poor complexity further increases the risk of extinction for small, isolated populations because refugia from extreme environmental events are lacking (Pearsons et al. 1992, Saunders et al. 1990; Sedell et al. 1990). Hilderbrand and Kershner (2000) estimated that 8 km of stream length are required to sustain an isolated population of cutthroat trout with high abundance (0.3/m).

Interactions with non-native species have also had an impact on resident populations of westslope cutthroat and bull trout. Brook trout X bull trout hybridization appears to be the most prevalent problem in isolated populations (Markle 1992). Competitive interactions with introduced species (mainly brook trout) have likely contributed to depressed cutthroat trout populations in the Lower Pend Oreille Subbasin. Of the streams surveyed by the Kalispel Natural Resource Department (KNRD) in the Lower Pend Oreille Subbasin, the highest cutthroat trout densities have been observed in streams and headwater reaches where brook trout were absent. Several studies indicate that abiotic factors (e.g. water temperature and velocity) may determine which trout species will be dominant in a given length of stream (De Staso and Rahel 1994; Griffith 1988).

The habitat restoration portion of this project primarily addresses factors that limit native tributary populations. Our in-channel restoration increases habitat complexity, which provides refugia during extreme environmental events and, therefore, lowers the extinction risk for the targeted populations. The Kalispel Tribe (Tribe) recognizes that instream habitat restoration is a temporary solution to habitat degradation and that recovery will only occur when future human impacts are minimized and watershed processes are restored. The Tribe has and will pursue opportunities for watershed restoration projects. However, watershed restoration will not yield significant improvements for years or decades. The Tribe also recognizes that some of the native fish populations in the Lower Pend Oreille sub-basin will not persist for years or decades. In some watersheds, individual native fish sightings are rare or populations are isolated in small tributaries. Restoration attempts to increase the habitat attributes that are limiting while the brook trout removal portion of this project will eliminate the threats associated with competition and hybridization with the native populations.

In summary, KNRD's plan for recovering native salmonid populations is:

1. Perform baseline stream habitat and fish population assessments to determine current distribution and abundance and identify core watersheds where recovery efforts will be focused.
2. Work to protect existing native populations and good habitat through participation in regional policy setting groups and consultation with area land, fish, and wildlife management agencies.
3. Pursue funding from various sources and participate jointly with other agencies in watershed restoration projects.
4. Implement instream and riparian restoration in identified recovery areas.
5. In recovery areas with non-native populations: 1) capture and relocate native fish, 2) treat streams to remove non-native species, and 3) translocate genetically identical or similar native fish from sister watersheds.
6. Monitor restoration and adapt management plans if needed.

The Kalispel Resident Fish Project began in 1995 with the selection of the study tributaries, habitat assessments, and assessment of fish populations in those tributaries. These baseline surveys showed that fish habitat is generally poor due to a lack of large woody debris, lack of pool type habitat, and high volumes of fine sediment. As a result of these conditions, rearing, spawning, and winter habitat were identified as limiting factors to fish populations in most reaches.

Based on the assessments taken during that initial field season, a process was developed to filter out the reaches of those tributaries that contained the most numerous limiting factors to fish habitat quality and quantity (KNRD & WDFW 1997a). A set of recommended enhancement measures was subsequently developed for each of these reaches that are intended to address the specific habitat shortcomings. This list of recommendations was implemented during field season 1996 and became the core for additional recommendations for 1997 and 1998. Field season 1998 was the last year of implementation for recommended enhancement measures on the seven designated study tributaries. Post assessments of habitat and fish populations were conducted the year following implementation and on an annual basis thereafter.

2003 marked the fifth, sixth and seventh years of conducting monitoring and evaluation on structures that were implemented from 1996 to 1998. Comparative analyses of changes in habitat attributes and changes in fish abundance using graphical displays were conducted following the 2003 field season. Also, the monitoring data has been examined for trends that may indicate which specific types of enhancement measures provide the greatest increase in habitat quality and quantity.

The Upper Columbia United Tribes Fisheries Center conducted a three-year baseline study to assess the fishery improvement opportunities on the Pend Oreille River (Ashe 1994). Based on earlier estimates of aquatic macrophyte community composition (Falter et al. 1991) and limited overwinter survival of age 0^+ largemouth bass (Bennett and Liter 1991), they suggested that the winter reduction in macrophyte communities created higher predation rates on age 0^+ bass. This led to their recommendation for the construction and placement of artificial cover structures to increase the amount of winter cover available in the reservoir. Baseline species abundance was determined by electrofishing the selected treatment and control sloughs prior to structure placement. In

1997, 100 Berkley artificial structures and 100 Pradco artificial structures were constructed and placed in the study sloughs. Treatment and control sloughs have been sampled twice annually since implementation of the habitat structures. In 2003, data continued to be examined to determine: 1) if artificial structures may provide the missing winter cover component, and 2) if a difference exists between the efficiency of the Pradco and Berkley structures.

DESCRIPTION OF STUDY AREA

Habitat and snorkel surveys were conducted in Ruby Creek (Figure 1), Harvey Creek and four tributaries to Harvey Creek (Figure 2). Ruby Creek is located on the west side of the Pend Oreille River and flows into the river just south of the resort community of Blueslide, WA. The Ruby Creek watershed drains approximately 79.7 Km^2. The mean annual discharge in the lower sections of Ruby Creek is approximately 1.0 cfs. The dominant geology is comprised primarily of glacial and alluvial deposits. A portion of Ruby Creek between reach 1 and 2 was not surveyed because of lack of access due to private property.

Harvey Creek is a larger watershed draining approximately 96.5 Km^2. The watershed drains into the southern end of Sullivan Lake, just east of the town of Metaline Falls, WA. The lower and upper portion of the Harvey Creek watershed is checker boarded between USFS lands and privately owned lands. In 1926 forest fires burned almost the entire Harvey Creek watershed. The mouth of Harvey Creek is influenced by the elevation of Sullivan Lake. The dominant geology is comprised primarily of glacial and alluvial deposits.

METHODS

Stream and fish population survey methodologies used within the Box Canyon Reach were similar to those developed by Espinosa (1988) and further revised by Huntington and Murphy (1995). Habitat data survey were collected in two ways: 1) at a transect directly perpendicular to the stream thalweg, and 2) in the 30 m interval that separated adjacent transects. Primary pools, spawning habitat, unstable banks, and acting woody debris were identified and enumerated in the entire length of each 30 m stream segment between two transects. Data for the remainder of the habitat attributes (Table 1) were collected at the end of each 30 m segment: the actual transect site. Reaches were defined by lengths of stream channel with common confinement, gradient, and substrate (Rosgen, 1994). Breaks between two homogeneous areas defined a new reach. Reach overviews were completed at the end of each reach; these contained written descriptions of prominent features and/or potential impacts to habitat quality. Each reach was permanently marked, flagged and geo-referenced using a Trimble Geo-explorer III receiver.

Temperature loggers were placed in the lower portion of each stream and recorded temperature on hourly intervals. Loggers were also placed in the middle and/or upper sections of some of the larger streams.

Fish density estimates for baseline surveys were collected using standard snorkel survey techniques (Espinosa 1988). Sampling was conducted during the period from July 15 through September 30. Snorkeling data included species, number, and sizes; data were summarized to species of fish per 100 m^2. The standard size/age classes for salmonid species were determined according to Espinosa (1988). Lengths of baseline snorkel stations

were 100 m and selected so that the area snorkeled is representative of the reach. Fish stations were permanently marked and flagged using aluminum tags and flagging.

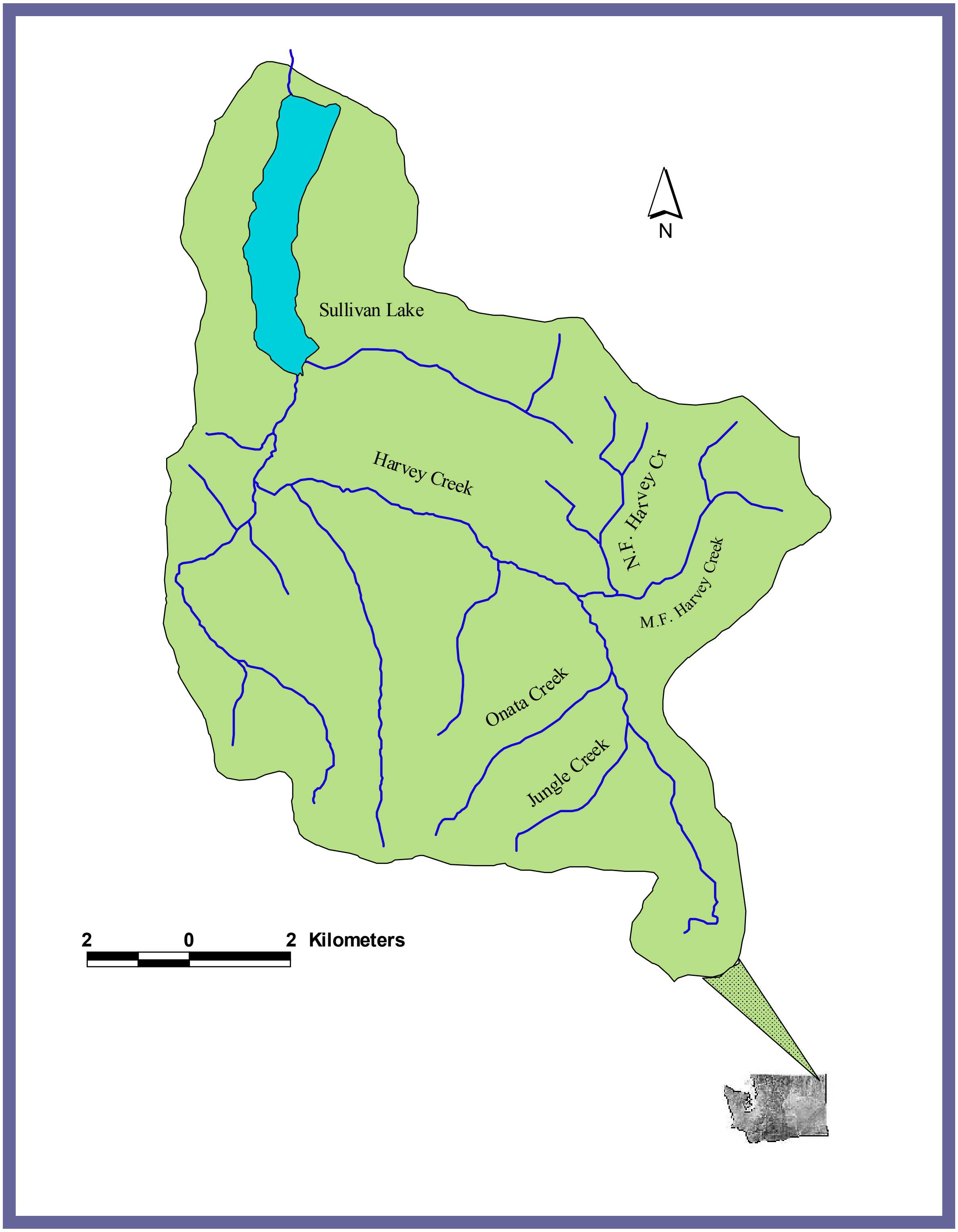

Figure 1. Harvey Creek watershed.

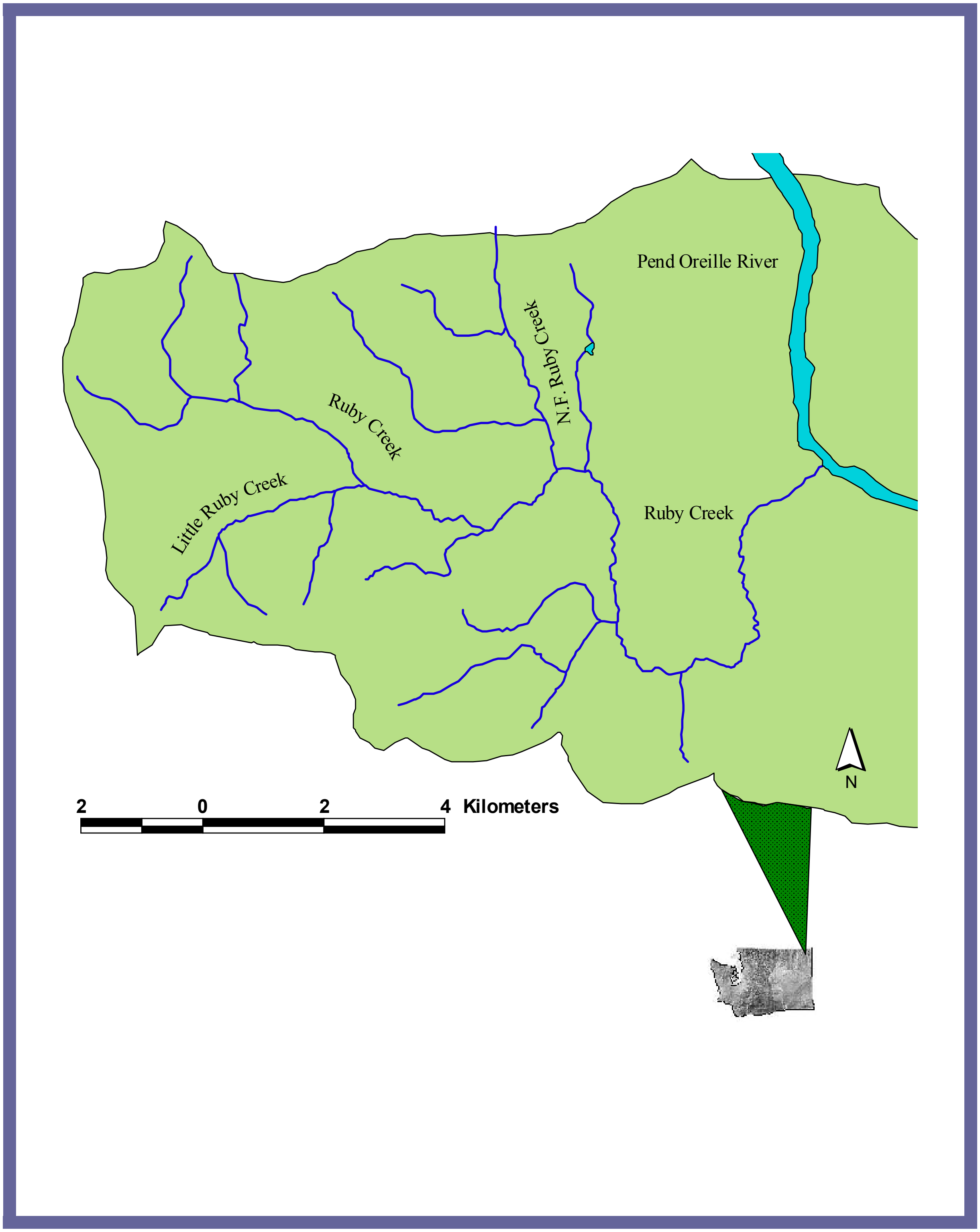

Figure 2. Ruby Creek watershed.

Table 1. Transect variables and method of collection.

Variable	Method of collection
Habitat Type	Visually determine habitat types (i.e., pool, riffle, glide, pocketwater, run, alcove).
Dominant Substrate Size	Visually determine largest percentage of substrate for that habitat type (i.e., silt, sand, gravel, cobble, boulder, bedrock).
Habitat Function	Visually determine habitat functions (i.e., winter, summer, spawning or unusable).
Spawning Gravel Amount and Quality	Estimate potential square meters of spawning gravels between transects and rate quality (i.e. gravel size, location and current velocity Kalispel internal doc.1-95) Good = All criteria met. Fair = 2 criteria met. Poor = 1 criteria met.
Stream Depths	Measure depth at 1/4, 1/2, 3/4 across channel to the nearest cm.
Habitat Widths	Measure each specific habitat type in a transect to the nearest 0.1m.
Primary Pools	Number of pools with length or width greater than the avg. width of stream channel between transects.
Pool Quality	Rating based upon collection of length, width, depth, and cover.
Pool Creator	Identify item creating the pool (e.g., large woody debris, boulders, beaver, enhancement, other).
Cobble Embeddedness	Visual estimate of the percentage fine or coarse sediment surrounding substrate at transect. Actual measurement was recorded with an embed meter approximately every 20 transects. Regression of the estimated numbers with the actual measurements calculated a correction factor for all estimated values.

Table 1. *continued*

Variable	Method of collection
Bank Stability	Visual estimate of the length of unstable bank between transects for possible sediment source.
Instream Cover Rating	Percent of the stream surface covered by large woody debris, aquatic vegetation, bank vegetation in or near the surface of the water/ Amount of cover provided by undercuts, root wads, boulders or turbulence.
Dominant/Subdominant Riparian Vegetation	Visual estimate of dominant vegetation and of subdominant vegetation species.
Stream Channel Gradient	Using a clinometer measure percent slope.
Acting Woody Debris	Number of woody debris with a diameter >10cm and a length >1m within the wetted channel.
Potential Debris Recruitment	Number of trees within the transect that could potentially fall into the stream > 10 cm and a length > 1m.
Measurements for Residual Pool Depth	Measure average pool depth at the deepest portion of the pool and at the pool tailout. Measure to the nearest cm.
USFS Large Woody Debris	Number of woody debris with a diameter >30cm and a length >10m with some portion within the wetted channel.

RESULTS

Ruby Creek

Twelve reaches totaling 17.8 Km (11.1 miles) were surveyed in the mainstem Ruby Creek. The survey began at the confluence of the Pend Oreille River (elevation 652 m) and was terminated in the headwaters near an elevation of 1146 m (Figure 3). This watershed has been logged and grazed historically and was being heavily grazed at the time of the survey. Brook trout were observed throughout the surveyed portion of the stream with the exception of reach 1 (Figure 4). Westslope cutthroat trout were observed in all reaches except reaches 2, 3, and 11. An old log crib dam located in reach 2 appeared to be a barrier to fish passage. A natural fish passage barrier in reach 9 was observed. However, brook trout and westslope cutthroat trout were found above each barrier. Four thermographs were placed in Ruby Creek to monitor water temperatures (Figure 5,6,7, and 8). The highest temperature was recorded on the lowest thermograph site: 19.9°C on July 29th (Figure 5). The highest temperature recorded on the upper thermograph site was 12.9 °C on July 26th (Figure 6).

Figure 3. Fish distribution and reaches surveyed in the Ruby Creek watershed.

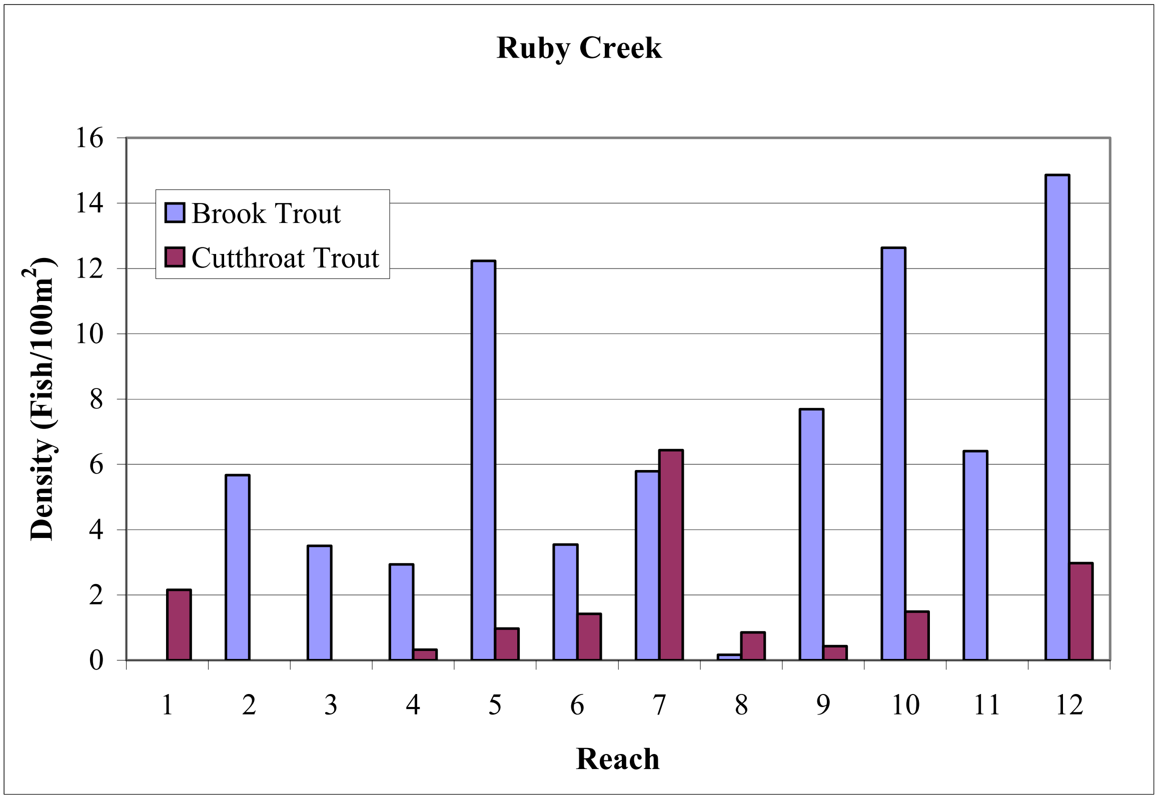

Figure 4. Fish densities for stations snorkeled in Ruby Creek.

Reach 1

Reach 1 of Ruby Creek began at the confluence with the Pend Oreille River. The reach was 1950 m in length and classified as a Rosgen A2 channel type (Table 2). The dominant substrate in the reach was rubble followed by boulders. Little spawning habitat (4 m^2) was observed (Table 3). Instream cover in the reach was high (3.5) due to a dominance of riffle type habitat (Table 4). Cutthroat trout were the only species observed in the reach with a density of 2.1/100 m^2.

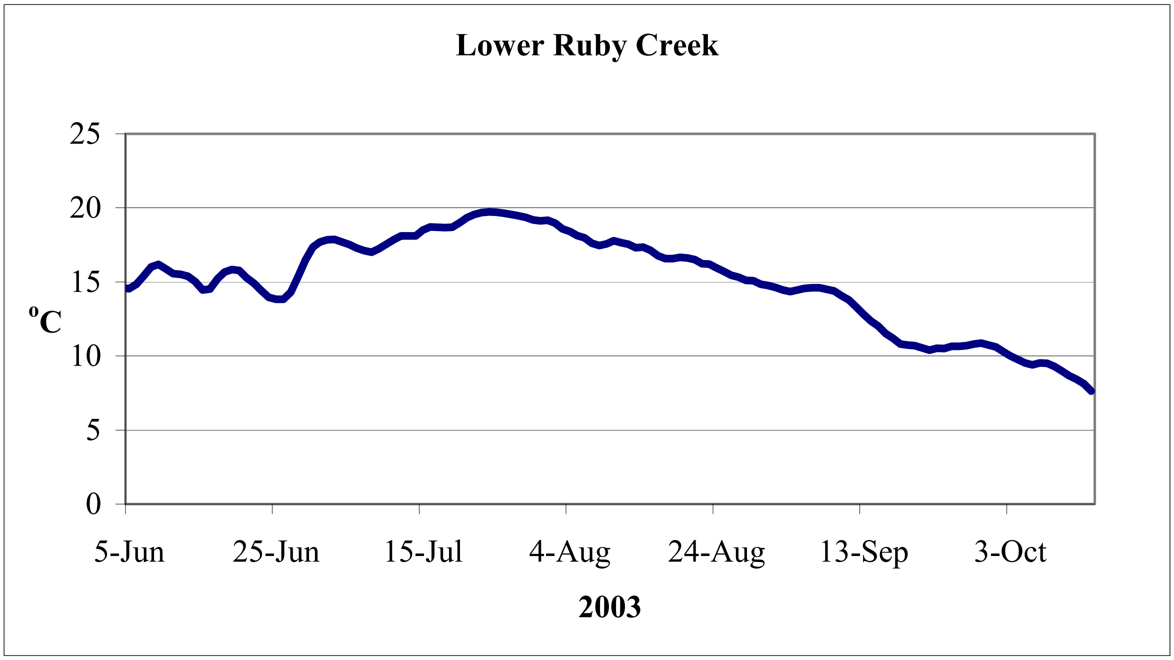

Figure 5. 7 day average daily maximum temperatures for lower Ruby Creek.

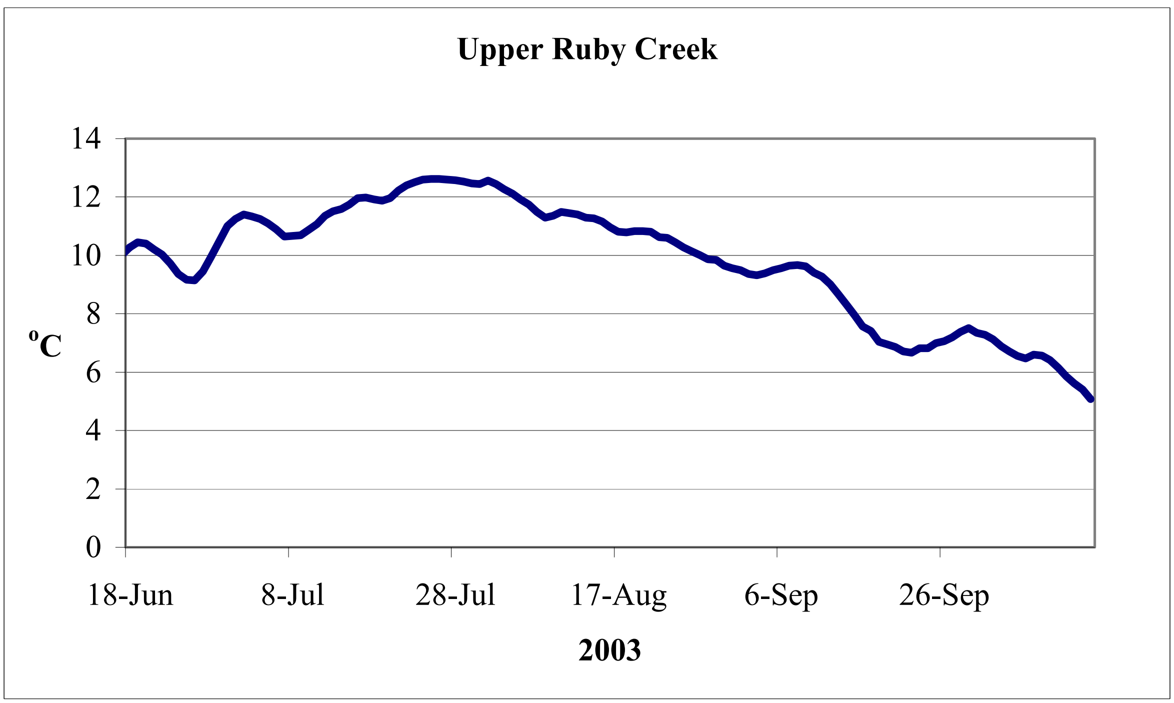

Figure 6. 7 day average daily maximum temperatures for upper Ruby Creek.

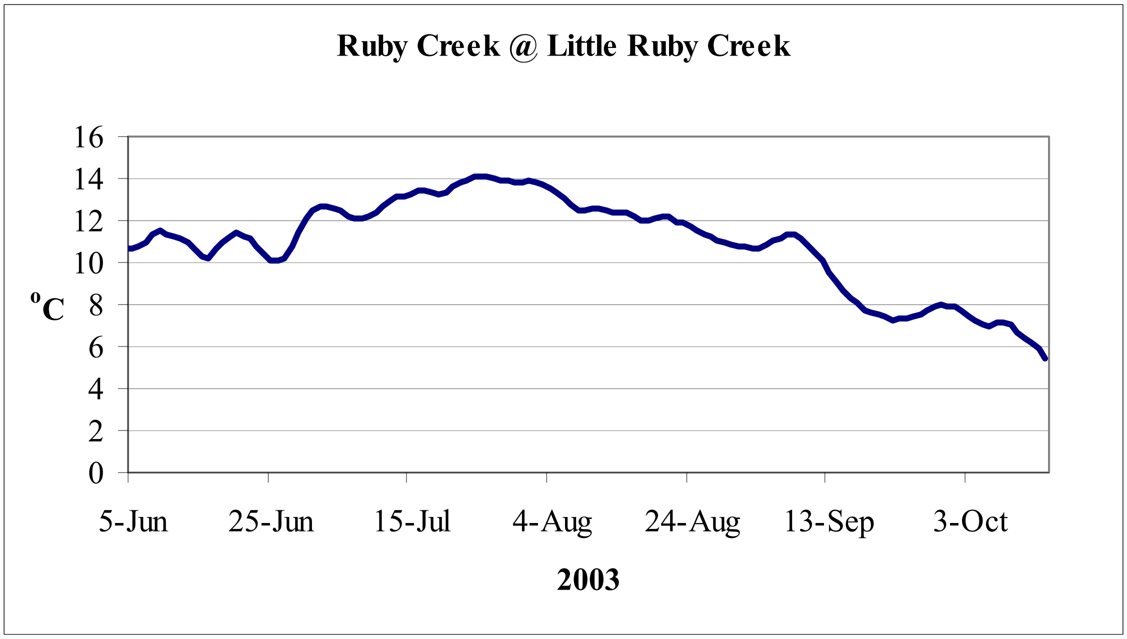

Figure 7. 7 day average daily maximum temperatures recorded at the confluence of Little Ruby Creek.

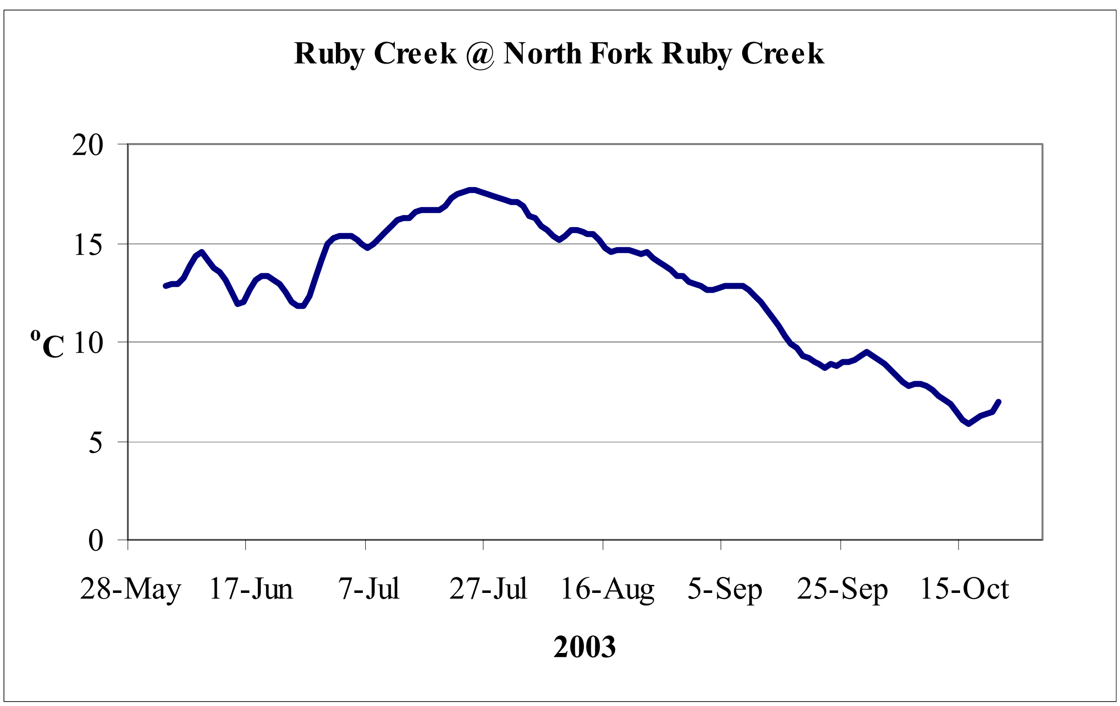

Figure 8. 7 day average daily maximum temperatures recorded at the confluence of North Fork Ruby Creek.

Table 2. Channel characteristics for reaches surveyed in Ruby Creek.

Ruby Creek				
Reach	Channel Type	Average Gradient (%)	Dominant Substrate	Bankfull W:D
1	A2	4.8	Rubble	14.8
2	C3	1.8	Cobble	16.6
3	C3	1.7	Cobble	30.5
4	C3	1.3	Cobble	13.4
5	B3	2.3	Cobble	15.8
6	B4	2.0	Small Gravel	
7	C4	1.7	Gravel	12.2
8	G6	2.5	Silt	11.0
9	A2	7.1	Boulders	10.3
10	C4	1.5	Small Gravel	12.0
11	E5	1.8	Sand	5.4
12	E6	1.8	Silt	6.8

Table 3. Ruby Creek limiting factors attributes. Shading indicates that the value exceeded the threshold limits.

Ruby Creek							
Reach	Substrate Embedded (%)	Bank Stability (%)	Bank Cover	Instream Cover	Pool : Riffle	Spawning Gravel (m^2)	Primary Pools/ Km
1	50	98	1.8	3.5	0.2	4.0	8.7
2	51	98	2.2	2.2	0.2	2.0	5.6
3	54	99	2.9	2.5	0.3	14.5	8.3
4	63	99	4.3	3.9	0.5	0.5	4.9
5	60	98	2.7	2.5	0.1	9.5	9.5
6	64	97	2.9	2.6	0.1	72.0	12.3
7	51	92	4.0	3.6	0.3	10.0	6.7
8	51	98	4.1	3.8	0.2	18.0	6.5
9	39	100	4.3	4.4	0.2	26.0	11.3
10	63	100	4.0	4.2	0.5	54.0	21.2
11	97	91	2.4	2.1	0.4	1.5	8.0
12	81	94	4.4	4.5	1.8	0.5	1.2

Table 4. Habitat attributes for reaches surveyed in Ruby Creek.

Ruby Creek							
Reach	Average Depth (cm)	Average Width (m)	Residual Pool Depth (cm)	Percent Pool	Percent Riffle	Percent Pocketwater	Acting LWD (No./100m)
1	25.0	6.1	86.8	11	70	0	17.4
2	22.1	5.5	83.6	12	56	0	12.9
3	23.4	5.7	73.0	17	54	0	17.8
4	26.8	7.9	82.5	44	30	0	15.4
5	19.3	4.8	58.0	8	64	0	25.7
6	19.7	4.2	67.1	14	50	0	34.1
7	18.3	3.9	75.0	19	46	0	23.4
8	18.2	4.4	59.8	27	60	0	18.4
9	18.3	3.9	53.3	16	69	0	29.8
10	25.8	5.2	46.7	31	42	0	25.4
11	17.1	2.3	72.0	23	52	0	39.3
12	19.0	13.2	110.0	93	4	0	16.6

Reach 2

Reach 2 of Ruby Creek began approximately 800 meters above reach 1. This was due to the denial of access by a private landholder. Reach 2 was 1260 m in length and classified as a Rosgen C3 channel type. The reach was heavily impacted from grazing and contained a diversion dam for cattle watering. The heavy grazing contributed to a low bank cover rating (2.2). Large woody debris in reach 2 was the lowest of the 12 reaches surveyed (12.9 pieces per 100 m). Brook trout was the only fish species observed in the reach with a density of 5.7 fish/100 m^2.

Reach 3

Reach 3 was 1800 m in length and classified as a Rosgen C3 channel type. Reach 3 had little pool habitat (17%); excess fine sediment has filled in pools. The reach contained a large mass wasting area that was approximately 12 m in length and 30 m in height (Figure 9). Brook trout were the only species observed in this reach, at a relatively low density (3.5/100 m^2). The dominant riparian vegetation was composed primarily of seral species (red alder and lodgepole pine). This is most likely due to continued grazing along the streambanks.

Figure 9. Mass wasting on Ruby Creek reach 3.

Reach 4

Reach 4 was classified as a Rosgen C3 channel type that was 1230 m in length. The first 360 m of the reach consisted of a beaver pond complex. Due to the beaver ponds, this reach had high pool composition (44%). The reach has been heavily grazed resulting in the seral species in the riparian zone (red alder, and lodgepole pine). Westslope cutthroat trout (0.3/100 m^2) and brook trout (2.9/100 m^2) were observed in the snorkel station. Limiting factors within the reach appear to be a lack of spawning gravels (0.5 m^2) and a low quantity of LWD (15.4 pieces per 100 m).

Reach 5

Reach 5 was 1050 m in length and classified as a Rosgen B3 channel type. The reach contained the lowest pool habitat (8%), low pool to riffle ratios (0.1), and a low primary pool frequency (9.5/Km). The lack of pools also resulted in a lower residual pool depth (58 cm). Like reach 3 and 4, heavy cattle grazing had also impacted reach 5. The brook trout density was one of the highest in the survey at 12.2/100 m^2. Westslope cutthroat trout were also observed (1.0/100 m^2). Due to lack of pools, over wintering habitat appears to be a limiting factor.

Reach 6

Reach 6 was classified as a Rosgen B4 channel type that was 1380 m in length. In this reach the riparian vegetation was transforming back into climax species (red cedar 20%, Douglas fir 15%, and spruce 13%) likely resulting in the highest LWD count of the surveyed reaches (34.1 LWD/100 m). Spawning gravel was abundant: 72 m^2; however, most was poor quality. Fish densities were relatively low. Brook trout were observed at 3.1/100 m^2 and westslope cutthroat trout at 1.4/100 m^2 in the snorkel station.

Reach 7

Reach 7 was 900 m in length and classified as a Rosgen C4 channel type. The dominant substrate throughout the reach was gravel; however, only 10 m^2 was classified as spawning gravel. Abundant aquatic vegetation was observed for the first time in this reach. This was the first reach that westslope cutthroat trout densities (6.4/100 m^2) were higher than non-native brook trout (5.8/100 m^2). Like reach 4 and 5, grazing activity was high in reach 7. Due to the lack primary pools (6.5) over wintering habitat appears to be one of the limiting factors.

Reach 8

Reach 8 was 1530 m in length and classified as a Rosgen G6 channel type. The reach contained a large beaver pond that was approximately 70 m in length and averaged 1.5 m in depth. Silt was the dominant substrate in the reach, due to the large beaver ponds. Many undeveloped campsites were observed throughout the reach causing compacted soils and unstable banks. Bank and instream cover (4.1 and 3.8 respectively) were high in reach 8. Like reach 7, westslope cutthroat trout were the most abundant species observed (0.9/100 m^2) followed by brook trout (0.2/100 m^2).

Reach 9

Reach 9 was a Rosgen A2 channel type that was 2130 m in length. Reach 9 was the steepest reach with a mean gradient of 7.1 %. Due to the high gradient and a boulder dominated substrate the reach also had the lowest embeddedness estimate. A possible fish passage barrier was observed in the reach; however, brook trout and westslope cutthroat trout were found above the possible barrier. Bank and instream cover were rated the highest of all the reaches surveyed: 4.3 and 4.4, respectively. Brook trout density was 7.7/100 m^2. Westslope cutthroat trout density remained low at 0.4/100 m^2.

Reach 10

Reach 10 was 990 m in length and classified as a Rosgen B4 channel type. The dominant substrate in the reach was small gravel, therefore large quantities of spawning gravel were observed (54 m^2). Reach 10 also contained 21.2 primary pools/Km, the highest density in Ruby Creek. The top end of the reach contained a constricted culvert that may act as a passage barrier during high flow events. Brook trout density was relatively high (12.6/100 m^2), while; westslope cutthroat trout density was relatively low (1.5/100 m^2).

Reach 11

Reach 11 was 2010 m in length and classified as a Rosgen E5 channel type. Clearcuts, heavy cattle grazing, and upstream beaver ponds contributed to the lowest bank stability rating (91%) and highest embedness (97%) of the entire survey. The reach also had the highest quantity of LWD (39.3 LWD/Km) of the surveyed portion of Ruby

Creek. Brook trout densities fell from the previous reach to 6.4/100 m^2, while no westslope cutthroat trout were observed.

Reach 12

Reach 12 was 1620 m in length and classified as a Rosgen E6 channel type. The first 450 m of the reach consisted of a large beaver pond complex. As a result, the pool:riffle ratio (1.8) and pool composition (92%) were high. Brook trout densities were the highest in reach 12 (14.8/100 m^2). Westslope cutthroat trout were observed at a density of 2.9/100 m^2.

Harvey Creek

Eleven reaches totaling 15.6 Km (9.7 miles) were surveyed in Harvey Creek. The survey started at the confluence of Harvey Creek and Sullivan Lake (elevation 280 m) and was terminated at Bunchgrass Lake (elevation 458 m) (Figure 10). In the late summer, Harvey Creek generally flows subsurface in parts of reach 1 and 2. No fish were observed in reach 2 and only 1 fish was observed in reach 1 at the time of the survey. Westslope cutthroat trout was the only salmonid species observed. One possible natural passage barrier was observed in reach 9. Three thermographs monitored water temperature in Harvey Creek (Figure 11, 12, and 13). Water temperatures remained relatively cool throughout the summer. The highest temperature was recorded on the upper thermograph: 17 ^{o}C on July 30th.

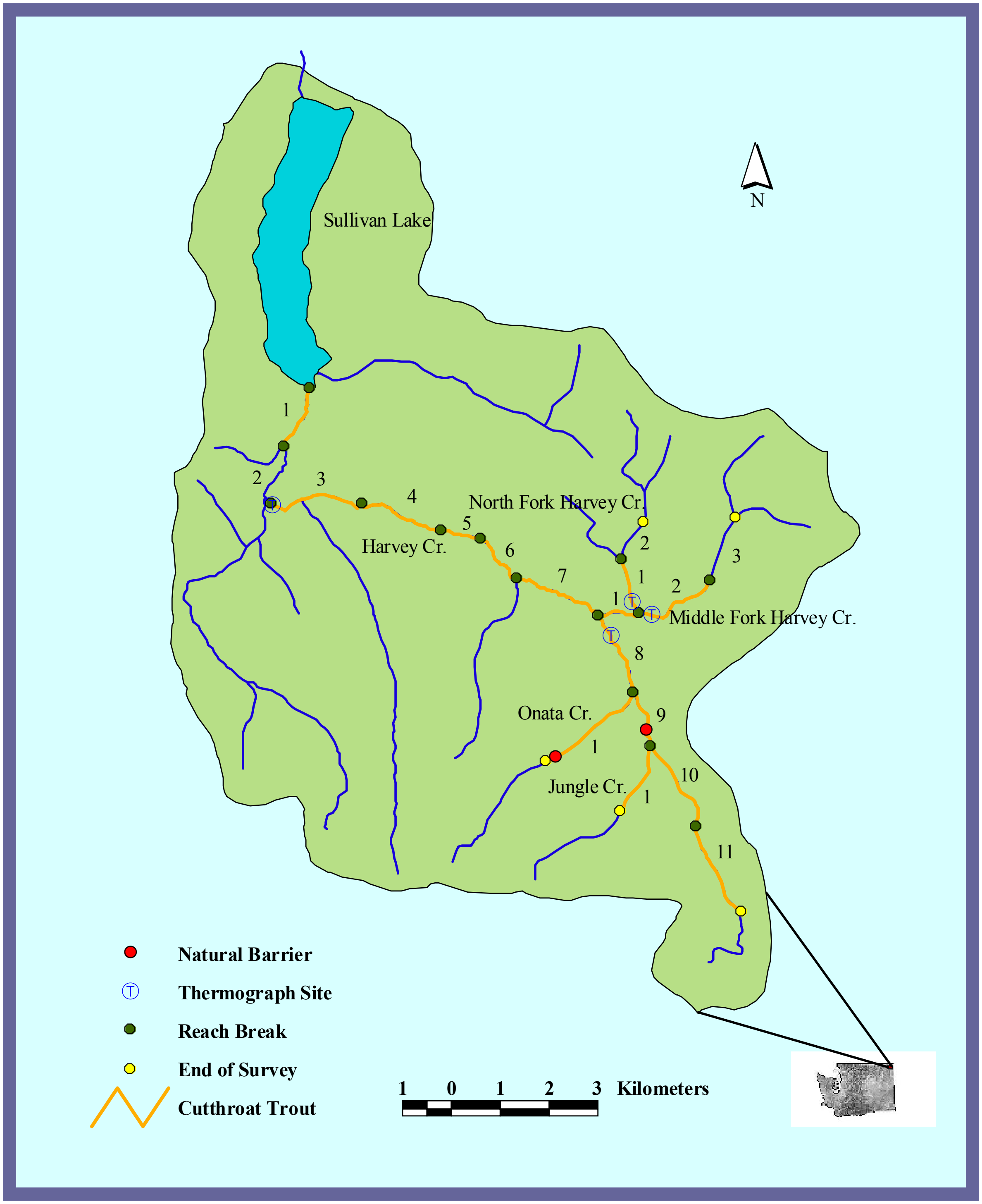

Figure 10. Fish distribution and reaches surveyed in the Harvey Creek watershed.

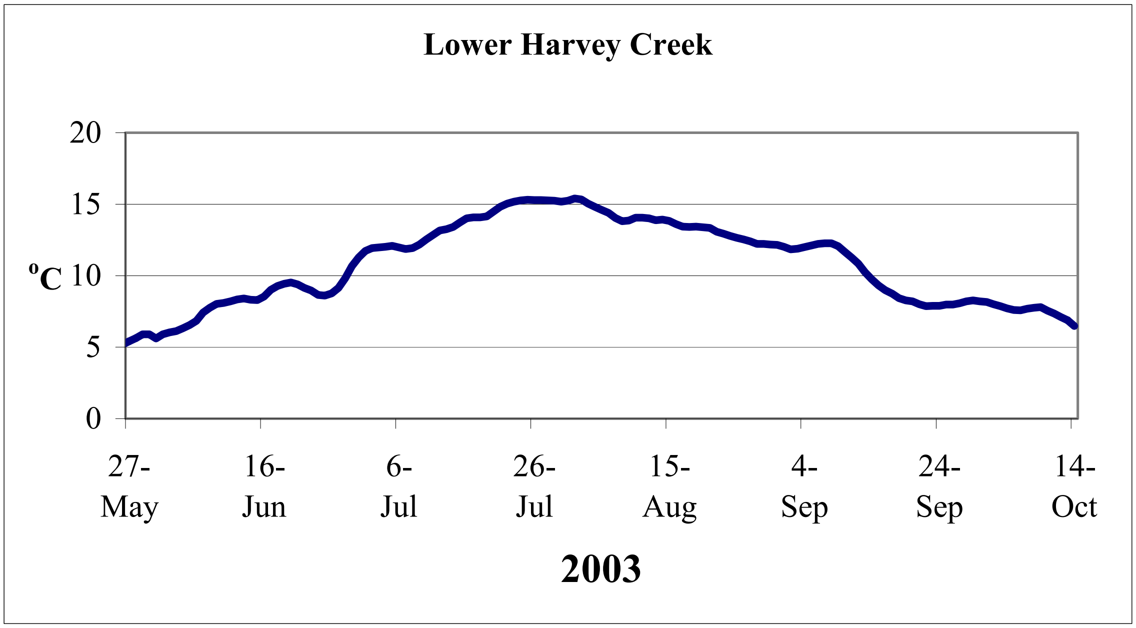

Figure 11. 7 day average daily maximum temperatures for lower Harvey Creek.

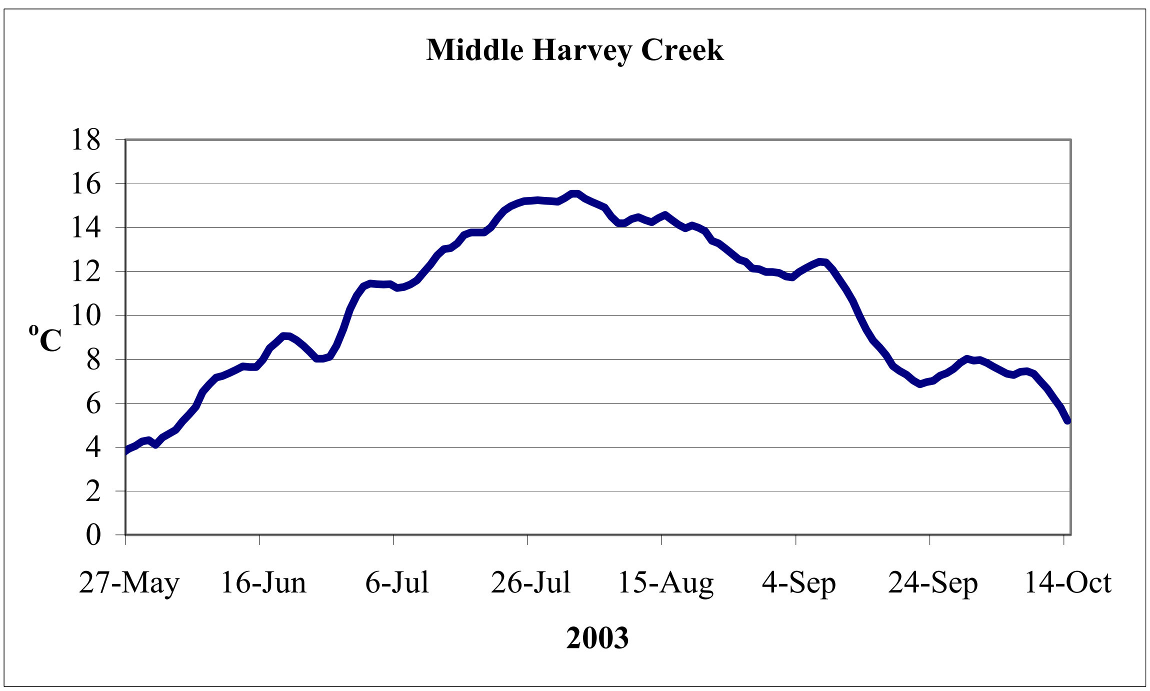

Figure 12. 7 day average daily maximum temperatures for middle Harvey Creek.

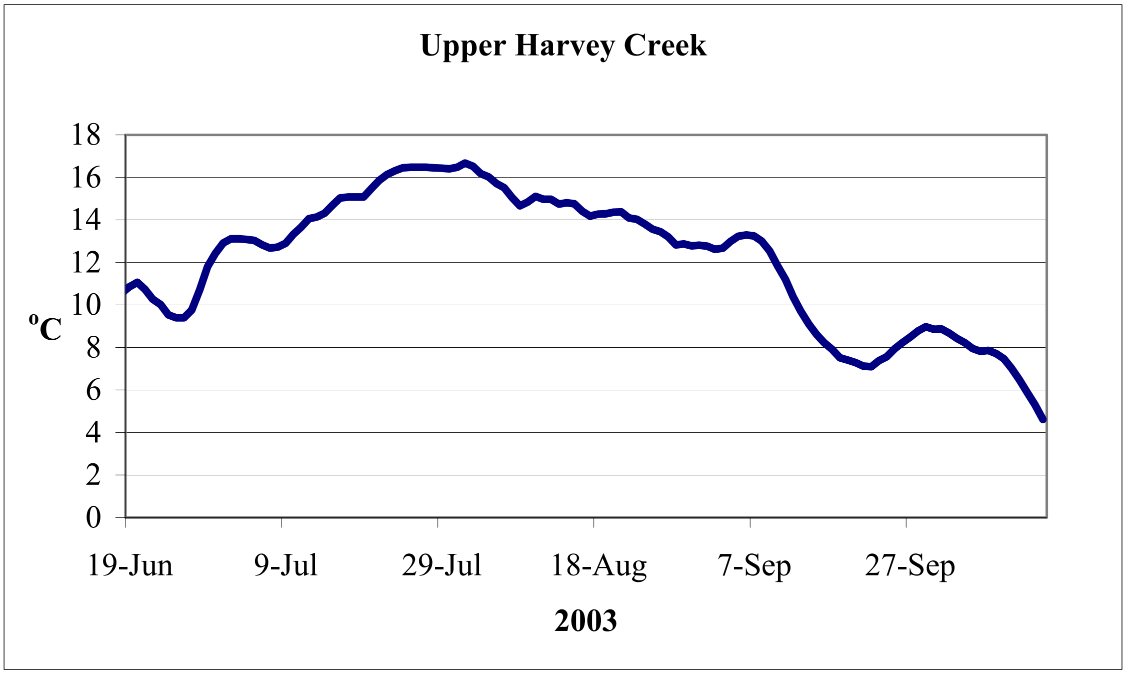

Figure 13. 7 day average daily maximum temperatures for upper Harvey Creek.

Reach 1

Reach 1 was 1110 m in length and classified as a Rosgen C3 channel type (Table 5). Riparian vegetation was sparse in reach 1 resulting in a low bank cover rating (1.2) and low LWD counts (10.3 LWD/100 m) (Table 6). The lack of LWD may also be contributing to the low primary pool count (2.7 primary pools/Km) (Table 7). Only 1 westslope cutthroat trout was observed in the reach 1 snorkel stations (Figure 14). Limiting factors in reach 1 include: lack of overwintering habitat, low LWD count, and lack of spawning gravels.

Table 5. Channel characteristics for reaches surveyed in Harvey Creek.

Harvey Creek				
Reach	Channel Type	Average Gradient (%)	Dominant Substrate	Bankfull W:D
1	C3	1.2	Cobble	16.3
2	C3	1.7	Cobble	16.0
3	A2	7.4	Boulder	14.6
4	B2	3.7	Rubble	16.5
5	B3	3.4	Rubble	17.6
6	B2	3.9	Rubble	18.1
7	B2a	4.9	Boulder	15.8
8	B2a	5.5	Boulder	15.8
9	B2	3.3	Boulder	22.5
10	A2	4.2	Boulder	8.5
11	A2	7.3	Rubble	9.5

Table 6. Habitat attributes for reaches surveyed in Harvey Creek.

Harvey Creek							
Reach	Average Depth (cm)	Average Width (m)	Residual Pool Depth (cm)	Percent Pool	Percent Riffle	Percent Pocketwater	Acting LWD (No./100m)
1	13.9	9.8	153.3	10	62	0	10.3
2	16.3	8.1	73.3	7	76	0	7.8
3	24.9	7.4	96.3	10	80	0	14.5
4	20.9	7.8	65	7	68	0	7
5	18.8	7.2	70	3	70	0	7.2
6	19.3	7.2	0	10	70	0	15.9
7	21.6	7.5	46	12	69	0	12.2
8	17.5	6.3	49	17	59	0	16.6
9	15.6	5.3	72.8	20	56	0	18.6
10	14.6	3.8	45.1	30	52	1.5	29.8
11	11.9	3.3	67	14	64	0	26.9

Table 7. Harvey Creek limiting factors attributes. Shading indicates that the value exceeded the threshold limits.

Harvey Creek							
Reach	Substrate Embedded (%)	Bank Stability (%)	Bank Cover	Instream Cover	Pool : Riffle	Spawning Gravel (m^2)	Primary Pools/ Km
1	36	94	1.2	1.0	0.1	2.0	2.7
2	39	95	1.6	1.7	0.1	3.0	2.3
3	6	99	1.0	2.2	0.1	1.0	4.1
4	38	100	2.1	1.8	0.1	5.0	6.9
5	32	100	1.6	2.4	0	0.5	2.9
6	37	98	2.5	2.0	0.1	0.5	0
7	43	96	2.7	1.7	0.1	6.0	4.3
8	55	99	3.5	2.7	0.3	3.5	16.0
9	44	98	3.8	3.1	0.2	6.5	12.1
10	52	100	3.3	3.0	0.5	64.0	7.6
11	37	98	2.2	1.7	0.2	1.5	2.7

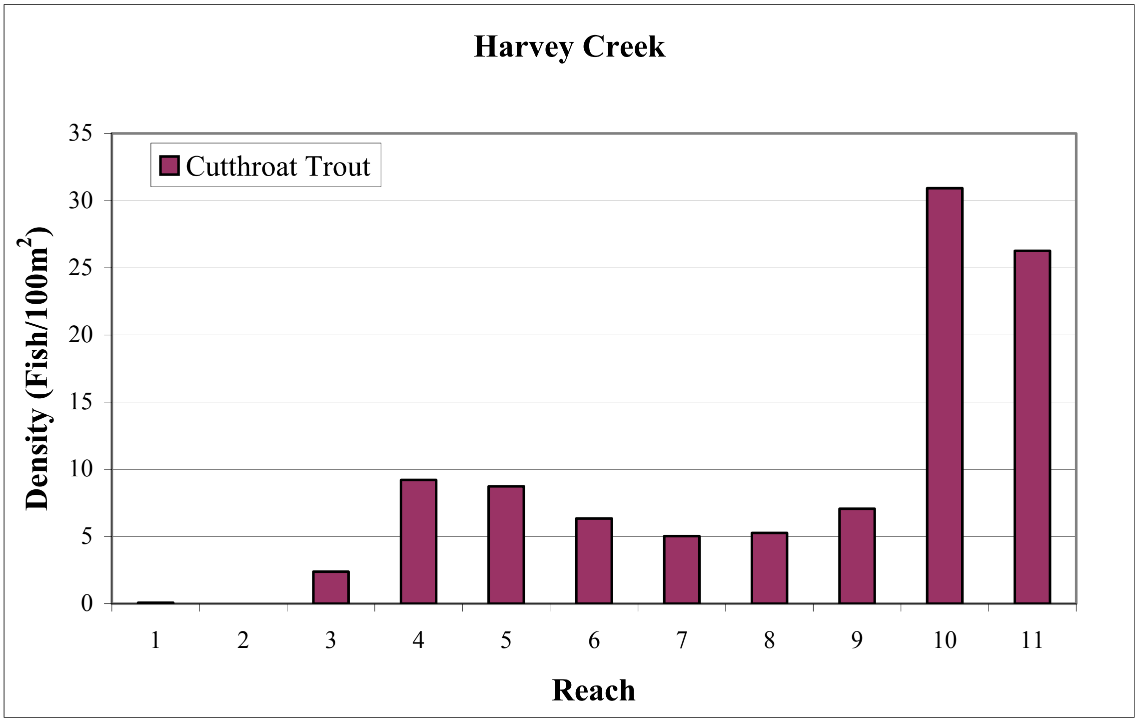

Figure 14. Fish densities for stations snorkeled in Harvey Creek.

Reach 2

Reach 2 was classified as a Rosgen C3 channel type and was 1320 m in length. The reach had a low LWD density (7.8 LWD/100 m) of the surveyed portion of Harvey Creek. Few spawning gravels were observed (3.0 m^2). Instream and bank cover were low; 1.6 and 2.3, respectively. No fish were observed in the reach 2 snorkel station.

Reach 3

Reach 3 was classified as a Rosgen A2 channel type and was 1950 m in length. This reach had the highest mean gradient (7.4) of all the reaches surveyed; therefore spawning gravels were generally transported through the reach and little spawning habitat was observed (1.0 m^2). The dominant substrate was composed of large boulders, rubble, and bedrock. Streambanks were mostly boulders and, therefore, cover was sparse (1.0). Cutthroat trout were observed again in reach 3 at a density of 2.4/100 m^2. Lack of wintering habitat and little spawning gravels appear to be the limiting factors.

Reach 4

Reach 4 was 1590 m in length and classified as a Rosgen B2 channel type. The reach contained the lowest LWD density (7.0 pieces/Km) of all the reach surveyed. This likely contributed to low, instream cover (1.8), pool to riffle ratio (0.1), and primary pool frequency (6.9 pools/Km) all falling below threshold values. Cutthroat trout density was 9.2/100 m^2. Limiting factors in reach 4 appeared to be the same as the previous 3 reaches, little spawning gravels and lack of overwintering habitat, and low numbers LWD.

Reach 5

Reach 5 was 690 m in length and classified as a Rosgen B3 channel type. The beginning of the reach contained a large debris jam. Only 0.5 m^2 of spawning gravels were observed within the reach. Bank cover (1.6) and primary pools (2.9 pools/Km) both fell below the threshold values. Cutthroat trout densities were relatively high at 9.2/100 m^2. Lack of wintering habitat and spawning gravels appeared to be the limiting factors in reach 5.

Reach 6

Reach 6 was classified as a Rosgen B2 channel type and was 960 m in length. No primary pools were observed in the reach. Instream cover (2.0) and the pool to riffle ratio (0.1) both fell below the threshold values. Cutthroat trout densities were relatively moderate at 6.3/100 m^2. Lack of winter habitat and spawning gravels appeared to be the limiting factors in reach 6.

Reach 7

Reach 7 was 1620 m in length and classified as a Rosgen B2a channel type. The dominant substrate throughout the reach was boulders. Instream cover (1.7) and the pool to riffle ratio (0.1) were both below the threshold values. Cutthroat trout densities were relatively moderate at 5.0/100 m^2. Lack of spawning gravels, (0.5 m^2) and wintering habitat (4.3 primary pools/Km) appeared to be the limiting factors.

Reach 8

Reach 8 was classified as a Rosgen B2a channel type and was 1560 m in length. The LWD frequency (16.6 pieces/Km) was high relative to previous reaches and likely resulted in an increase of pool habitat (17%) and primary pools (16.0/Km). However, cutthroat trout density remained relatively moderate at 5.3/100 m^2. Wintering habitat appeared to be more abundant in this reach than all the previous reaches. Spawning gravels (3.5 m^2) appears to be a limiting factor in this reach.

Reach 9

Reach 9 was 990 m in length and was classified as a Rosgen B2 channel type. Pool habitat continued to increase (20%) in this reach as a result of an increase in LWD (18.6/100 m). Reach 9 also had the highest bank cover (3.8) and instream cover (3.1) ratings of all the reaches surveyed. The reach contained a possible natural fish passage barrier, however fish were observed below and above the barrier (Figure 15). Cutthroat trout densities began to increase (7.1/100 m^2). Spawning gravels appears (6.5 m^2) to be a limiting factor within this reach.

Figure 15. Reach 9 Harvey Creek fish passage barrier

Reach 10

Reach 10 was 1980 m in length and classified as a Rosgen A2 channel type. The reach began at the confluence of Harvey Creek and Jungle Creek. Reach 10 had the highest frequency of LWD (29.8 pieces/Km) of all the reaches surveyed. This reach also contained the largest amount of spawning gravels (64.0 m^2) and the most pool habitat (30%). The high number of LWD trapped spawning sized gravels and also created abundant pool habitat. Reach 10 was the only reach surveyed that meet the pool to riffle ratio threshold value. The bank cover and instream cover rating were both moderate at 3.3 and 3.0, respectively. Cutthroat density was relatively high in reach 10 at 30.9/100 m^2.

Reach 11

Reach 11 was 1860 m in length and classified as a Rosgen A2 channel type. Several potential mass-wasting areas in the reach were observed along the roadway. The LWD frequency remained moderate in reach 11 (26.9 100 m). Bank cover, instream cover, and primary pool frequency all fell below the threshold limits. Cutthroat trout densities, however, remained relatively high at 26.3/100 m^2. Lack of spawning gravels (1.5 m^2) and winter habitat appeared to be the limiting factors in reach 11.

Middle Fork Harvey Creek

Three reaches totaling 3.6 Km (2.2 miles) were surveyed. The survey began at the confluence of Harvey Creek and Middle Fork Harvey Creek. Middle Fork Harvey

Creek was not snorkeled due to its small size. Minnow traps were used to sample species composition. Westslope cutthroat trout were the only species captured (Table 8). One thermograph monitored water temperature from May 20th until October 14th (Figure 16). The high temperature of 13.3 ^{o}C was recorded on August 14th.

Table 8. Minnow trapping data collected in Middle Fork Harvey Creek.

Stream	Reach	No. Traps Set	No. Captured	
			Brook Trout	Cutthroat Trout
Middle Fork Harvey Creek	1	4	0	2

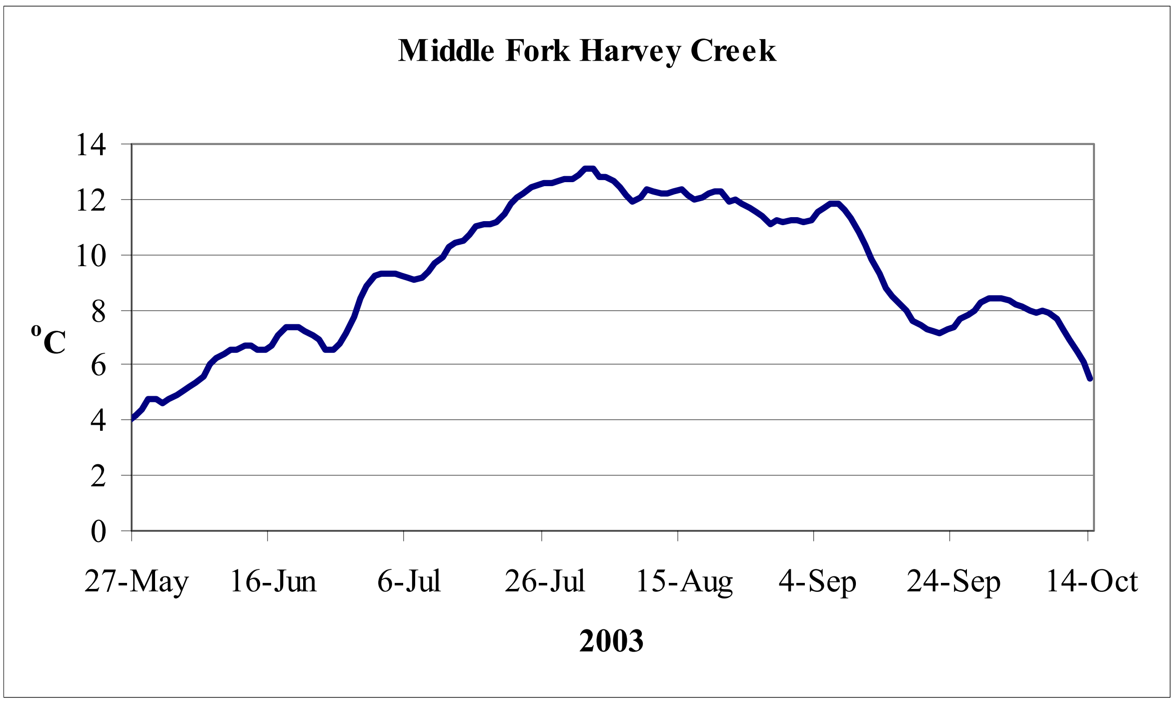

Figure 16. 7 day average daily maximum temperatures for Middle Fork Harvey Creek.

Reach 1

Reach 1 was 780 m in length and classified as a Rosgen A3 channel type (Table 9). All of the habitat characteristics values of reach 1 either met or exceed the threshold values (Table 10). The only limiting factor of reach 1 appeared to be the small quantity of spawning gravel available (Table 11).

Table 9. Channel characteristics for reaches surveyed in Middle Fork Harvey Creek.

Middle Fork Harvey Creek				
Reach	Channel Type	Average Gradient (%)	Dominant Substrate	Bankfull W:D
1	A3	10	Cobble	11.6
2	A3	5	Cobble	4.6
3	A3	10	Cobble	14.0

Table 10. Habitat attributes for reaches surveyed in Middle Fork Harvey Creek.

Middle Fork Harvey Creek							
Reach	Average Depth (cm)	Average Width (m)	Residual Pool Depth (cm)	Percent Pool	Percent Riffle	Percent Pocketwater	Acting LWD (No./100m)
1	21.3	4.5	58.2	28	62	0	32.4
2	13.3	3.3	85.0	9	45	0	56.1
3	9.6	3.4	82.5	4	56	0	57.1

Table 11. Middle Fork Harvey Creek limiting factor attributes. Shading indicates that the values exceeded the threshold limits.

Middle Fork Harvey Creek							
Reach	Substrate Embedded (%)	Bank Stability (%)	Bank Cover	Instream Cover	Pool : Riffle	Spawning Gravel (m^2)	Primary Pools/ Km
1	35	100	3.0	3.1	0.5	3.5	24.4
2	47	99	2.3	1.9	0.2	0	1.0
3	32	100	2.0	1.7	0	2	1.1

Reach 2

Reach 2 was 1050 m in length and classified as a Rosgen A3 channel type. Bank cover, instream cover, pool to riffle ratio, and primary pools/Km all fell below the threshold values. No spawning gravel was observed in reach 2. Lack of wintering habitat also appeared to be a limiting factor in this reach.

Reach 3

Reach 3 was 1800 m in length and classified as a Rosgen A3 channel type. This reach had the most LWD of the three reaches surveyed. However, abundant LWD did not increase spawning gravels or primary pool frequency. No fish were observed in reach 3 during the survey. Lack of winter habitat and spawning gravels appeared to be the limiting factors.

North Fork Harvey Creek

Two reaches totaling 2 Km in length were surveyed in North Fork Harvey Creek. The survey began at the confluence of Middle Fork Harvey Creek and North Fork Harvey Creek. Fish were sampled using minnow traps due to the small size of the stream. The only species captured was westslope cutthroat trout (Table 12). A thermograph was used to monitor water temperature between August 1st and October 14th. The high temperature of 9.1 ^{o}C was recorded on August 1st (Figure17).

Table 12. Minnow trapping data collected for North Fork Harvey Creek.

			No. Captured	
Stream	Reach	No. Traps Set	Brook Trout	Cutthroat Trout
North Fork Harvey Creek	1	4	0	8

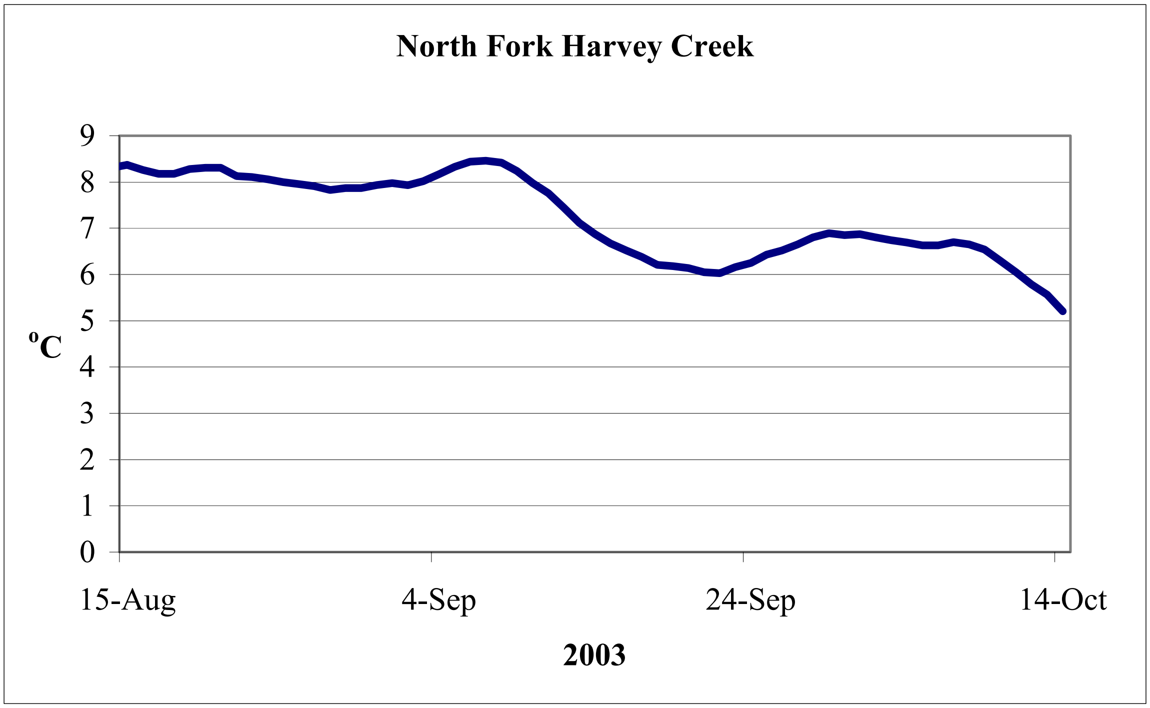

Figure 17. 7 day average daily maximum temperatures for North Fork Harvey Creek.

Reach 1

Reach 1 was classified as a Rosgen A4 channel type and was 1110 m in length (Table 13). At the top of the reach the stream is being diverted out of the channel and onto the forest floor by a large logjam. The reach had a relatively high embedness value of (74%), however spawning gravels were very abundant (Table 14). These high values likely result from a high LWD frequency (54.1 pieces/Km, Table 15).

Table 13. Channel characteristics for reaches surveyed in North Fork Harvey Creek.

North Fork Harvey Creek				
Reach	Channel Type	Average Gradient (%)	Dominant Substrate	Bankfull W:D
1	A4	5.3	Small Gravel	12.9
2	A3	4.5	Cobble	5.0

Table 14. North Fork Harvey Creek limiting factors attributes. Shading indicates that the value exceeded the threshold limits.

North Fork Harvey Creek							
Reach	Substrate Embedded (%)	Bank Stability (%)	Bank Cover	Instream Cover	Pool : Riffle	Spawning Gravel (m^2)	Primary Pools/ Km
1	74	96	2.9	1.8	0.1	47.0	6.3
2	43	97	1.7	1.3	0	7.0	3.2

Table 15. Habitat attributes for reaches surveyed in North Fork Harvey Creek.

North Fork Harvey Creek							
Reach	Average Depth (cm)	Average Width (m)	Residual Pool Depth (cm)	Percent Pool	Percent Riffle	Percent Pocketwater	Acting LWD (No./100m)
1	9.7	2.6	47.9	12	68	0	54.1
2	8.5	2.2	33.3	8	81	0	17.3

Reach 2

Reach 2 was 930 m in length and classified as a Rosgen A3 channel type. Instream and bank cover values both fell below the threshold. Very few primary pools were observed (3.2 pools/Km). Lack of spawning gravels (7.0 m^2) and wintering habitat appeared to be the limiting factors in reach 2.

Jungle Creek

Only one reach was surveyed in Jungle Creek. The survey began at the confluence of Harvey Creek and Jungle Creek. The reach was 1470 m in length and classified as a Rosgen A2 channel type (Table 16). Due to the small size of the stream, minnow traps were used to sample fish (Table 17). Westslope cutthroat trout was the only species captured in the traps. Bank cover (1.6), instream cover (1.3), pool to riffle ratio (0.1), and primary pool frequency (3.4 pools/Km) all fell below the threshold limits (Table 18). LWD values also were low in reach 1 of Jungle Creek (6.8/100 m, Table 19). A thermograph was used to monitor hourly stream temperature from June 11th to October 14th (Figure 18). Lack of spawning gravels (2.5 m^2) and over wintering habitat appeared to be the major limiting factors in Jungle Creek.

Table 16. Channel Characteristics for the reach surveyed in Jungle Creek.

Jungle Creek				
Reach	Channel Type	Average Gradient (%)	Dominant Substrate	Bankfull W:D
1	A2	5.9	Rubble	7.3

Table 17. Minnow trapping data collected for Jungle Creek.

Stream	Reach	No. Traps Set	No. Captured	
			Brook Trout	Cutthroat Trout
Jungle Creek	1	4	0	6

Table 18. Jungle Creek limiting factors attributes. Shading indicates the value has exceeded the threshold limits.

Jungle Creek							
Reach	Substrate Embedded (%)	Bank Stability (%)	Bank Cover	Instream Cover	Pool : Riffle	Spawning Gravel (m^2)	Primary Pools/ Km
1	55	100	1.6	1.3	0.1	2.5	3.4

Table 19. Habitat attributes for the reach surveyed in Jungle Creek.

Jungle Creek							
Reach	Average Depth (cm)	Average Width (m)	Residual Pool Depth (cm)	Percent Pool	Percent Riffle	Percent Pocketwater	Acting LWD (No./100m)
1	8.3	2.2	38.7	21	69	0	6.8

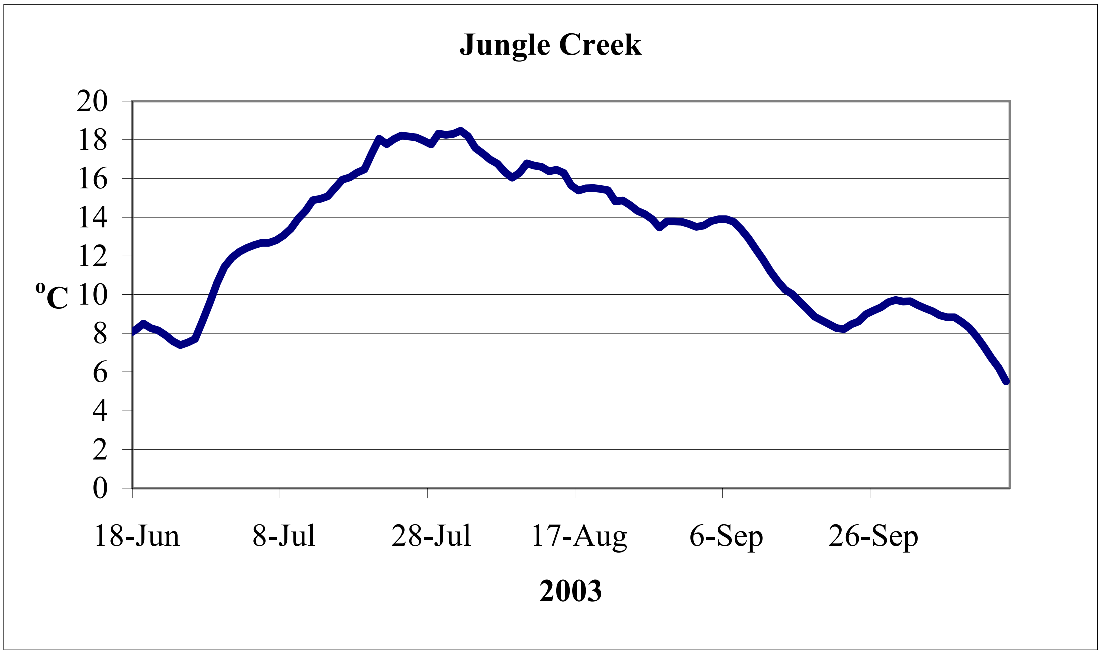

Figure 18. 7 day average daily maximum temperatures for Jungle Creek.

Onata Creek

One reach in Onata Creek was surveyed. The survey began at the confluence of Harvey Creek and Onata Creek. The reach was 2130 m in length and classified as a Rosgen A2 channel type (Table 20). The average gradient of the reach was 9.1% with a dominant substrate of rubble. Due to the size of the stream minnow traps were used to sample fish species. The only species captured was westslope cutthroat trout (Table 21). The reach contained several possible natural fish passage barriers; however, fish were noted above each. Bank cover and instream cover values both fell below threshold values (Table 22). LWD was relatively abundant at 29.5 pieces/100 m (Table 23). A thermograph was used to monitor hourly stream temperature from June 11th to October 14th (Figure 19). Lack of over wintering habitat appeared to be a limiting factor in the surveyed portion of Onata Creek.

Table 20. Channel characteristics for the reach surveyed in Onata Creek.

Onata Creek				
Reach	Channel Type	Average Gradient (%)	Dominant Substrate	Bankfull W:D
1	A2	9.1	Rubble	19.5

Table 21. Minnow trapping data collected for Onata Creek.

Stream	Reach	No. Traps Set	No. Captured	
			Brook Trout	Cutthroat Trout
Onata Creek	1	4	0	7

Table 22. Onata Creek limiting factor attributes. Shading indicates the value has exceeded the threshold limits.

Onata Creek							
Reach	Substrate Embedded (%)	Bank Stability (%)	Bank Cover	Instream Cover	Pool : Riffle	Spawning Gravel (m^2)	Primary Pools/ Km
1	29	98	1.1	1.3	0.1	9.0	5.6

Table 23. Habitat attributes for the reach surveyed in Onata Creek.

Onata Creek							
Reach	Average Depth (cm)	Average Width (m)	Residual Pool Depth (cm)	Percent Pool	Percent Riffle	Percent Pocketwater	Acting LWD (No./100m)
1	11.2	3.0	79.2	12.3	70	0	29.5

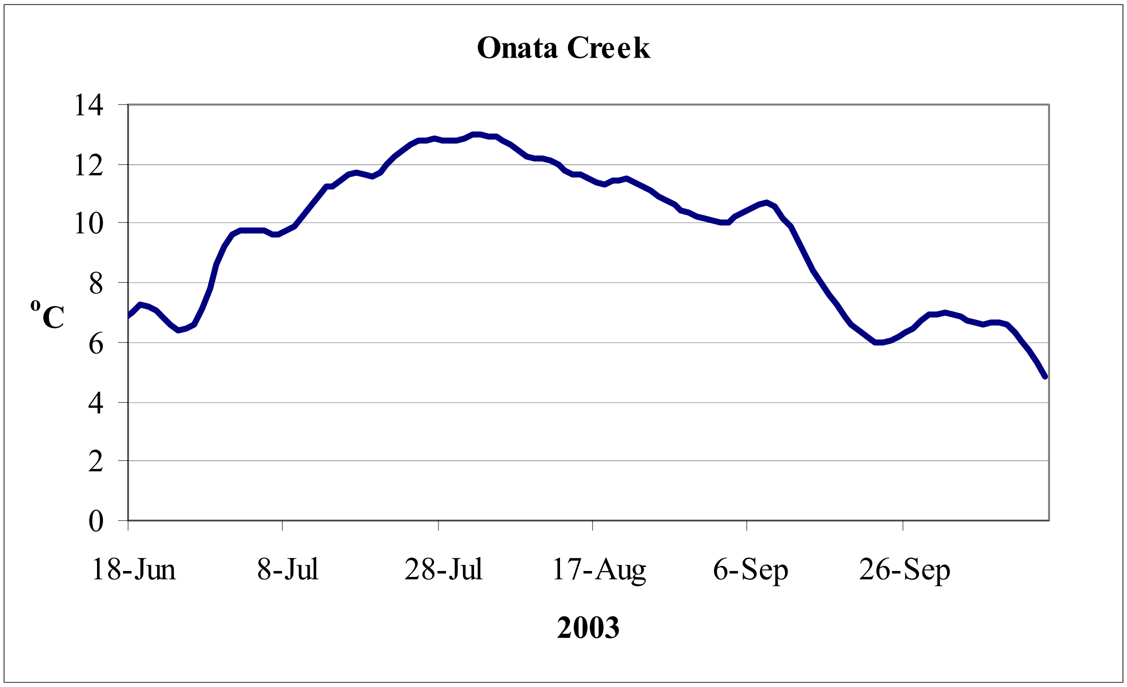

Figure 19. 7 day average daily maximum temperatures for Onata Creek.

Discussion

Various land-use and management activities can affect native salmonid habitats. This has lead to altered and degraded riparian areas, which have adversely impacted streams throughout the west. These riparian alterations have contributed to widespread declines of inland native fishes, which often favor exotic species (Griffith 1988). Generally, the land-use activities that have the greatest impact on stream habitat are timber harvest, mining, roads, and grazing. Anderson (1988), citing a 1986 report of the Montana State Water Quality Bureau, suggested that the single greatest threat to watersheds and aquatic life is timber harvest and associated road building within forests. Increased delivery of sediments, especially fine sediments, is usually associated with timber harvesting and road construction (Eaglin and Hubert 1993; Frissell and Liss 1986; Havis and others 1993). Roads contribute more sediment to streams than any other land management activity (Meehan 1991), but most land management activities, such as mining, timber harvest, grazing, and recreation are dependent on roads. Within the Ruby Creek watershed, logging, grazing, and roads have contributed to the degradation of the riparian area. Roads, both abandoned and in-service, run adjacent to Ruby Creek throughout much of the watershed. Some roads encroach on the riparian area and are causing channel constriction. Ideally, roads would be excluded from riparian zones because they are often a major source of soil erosion. In some cases as much as 90% of instream sediments have come from roads (Anderson et al. 1976).

Grazing and logging have both contributed to the low LWD densities observed throughout much of the survey. Continuous grazing of riparian areas reduces the establishment of climax species through the processes of browsing and soil compacting (Satterlund and Adams 1992). Recent and historic grazing of the Ruby Creek watershed has left much of the riparian vegetation simplified and in early seral stages. These activities have greatly reduced the availability of LWD recruitment.

Although stream degradation is detrimental to native salmonids, it generally favors introduced salmonid species, which are more tolerant to lower quality habitat conditions (Griffith 1988). Behnke (1979) described how clearcutting along two streams in the Smith River drainage of Montana increased erosion, sediment loads, and water temperatures. The westslope cutthroat population was eliminated in the disturbed area and brook trout became the principle species. However, a small area in the headwaters of one stream was not logged and a remnant cutthroat population still dominated in that reach. Platts (1974) also reported that cutthroat were common only in undisturbed reaches of stream in the Salmon River drainage of Idaho. In Ruby Creek, grazing heavily impacted reaches 2 and 3, while reaches 4 and 5 were unable to be grazed due to a thick understory of Spirea species. In reaches 2 and 3, the only species observed was non-native brook trout, however, in reaches 4 and 5 cutthroat trout were present. This supports that protection of high quality habitat is essential for the continued existence of native salmonid populations.

In 1926, the Harvey Creek drainage experienced a watershed wide forest fire. Impacts from the fire are still influencing fish habitat and land management practices throughout the watershed. Due to the fire, little suitable timber was left for commercial harvest. Timber harvest and associated road construction were minimal relative to other watersheds throughout the basin. It appeared that much of the riparian area burned. Consequently much of decadent wood for instream LWD recruitment has been absent since 1926. Low LWD densities have resulted in fewer primary pools and low pool to riffle ratios.

In Harvey Creek, there appears to be a relationship between fish densities and LWD densities (Figure 20). Fish use LWD for cover and LWD provides refugia during extreme flow events (Pearsons et al. 1992). Bull trout and cutthroat trout selected for habitat that contained LWD (Jakober et al. 1998). LWD contributes many important roles to fish populations and stream channels. Wood and boulders are primary factors in determining stream channel complexity. Pool formation, bank stabilization, modifying and maintaining channel morphology are all important function of LWD (Bisson et al. 1987; Ralph et al. 1994; Ruediger and Ward 1996).

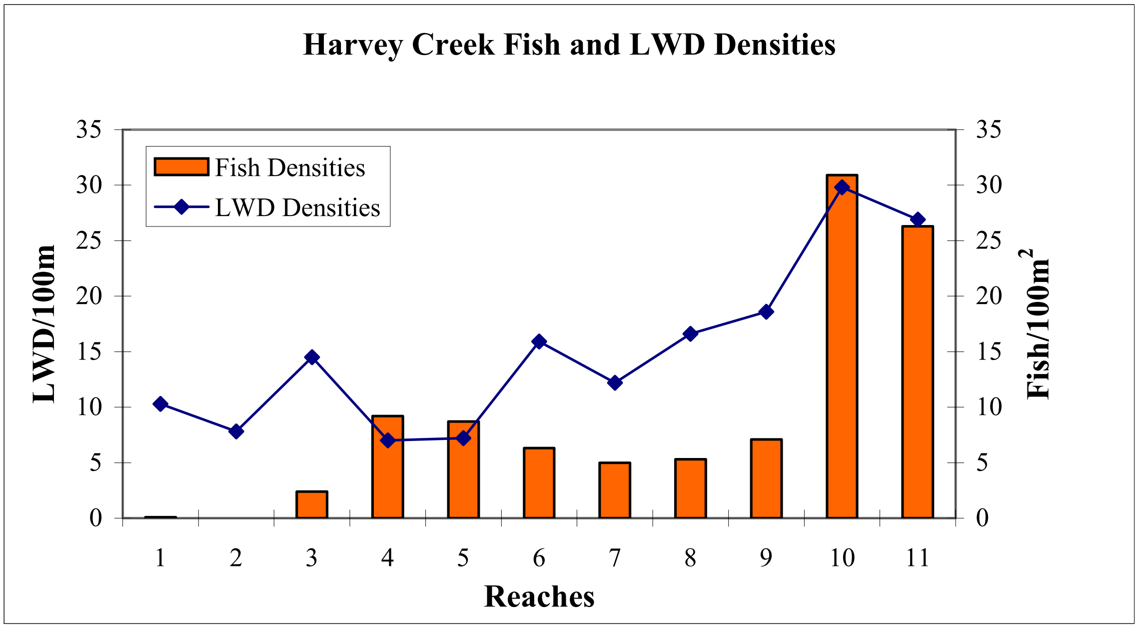

Figure 20. Harvey Creek fish densities associated to LWD densities.

Historically, non-native brook trout were introduced into Sullivan Lake, however, native westslope cutthroat trout were the only species observed in the Harvey Creek watershed. There are two factors that may have protected Harvey Creek from the invasion of brook trout: 1) Sullivan Lake never established a brook trout population and 2) on most years the lower two reaches of Harvey Creek flows subsurface early in the fall, creating a migration barrier to fall spawning fish.

In comparing the Harvey Creek and Ruby Creek watersheds, it is possible to see some of the effects land management practices and catastrophic events may have on individual watersheds. Ruby Creek's watershed appeared to be the more impacted of the two. The impacts were evident when looking at the habitat attributes and overall fish densities. In Rosgen channel types A-C, Ruby Creek's embeddedness was 12% to 18% higher than Harvey Creek (A channel 44-32, B channel 62-50, C channel 56-38, respectively). Ruby Creek's fish densities on average were also lower than Harvey Creek (overall densities 8 fish/100m^2 in Ruby Creek to 10 fish/100m^2 in Harvey Creek). The catastrophic fire in the Harvey Creek watershed has greatly reduced the impacts of land management practice by delaying commercial timber harvest and road construction associated with it. Harvey Creek also has not been impacted by grazing activities. It appears that the Ruby and Harvey Creek watersheds are in the best condition of any of the watersheds previously surveyed by the Kalispel Natural Resource Department.

BULL TROUT AND CUTTHROAT TROUT HABITAT ENHANCEMENT MONITORING

DESCRIPTION OF STUDY AREA

The Pend Oreille River begins at the outlet of Pend Oreille Lake, Idaho, and flows in a westerly direction to approximately Dalkena, Washington (Figure 21). From Dalkena the river turns and flows north into British Columbia where it joins the Columbia River. The approximate drainage area at the international border is 65,300 Km^2 (Barber et al. 1990). The normal high flow month is June with a mean discharge of 61,858 cfs, the normal low flow month is August with a mean discharge of 11,897 cfs (Barber et al. 1990). The Box Canyon Reservoir has 47 tributaries and covers 90 river kilometers of the Pend Oreille River, from Albeni Falls Dam at the southern border to Box Canyon Dam at the northern border.

Cee Cee Ah Creek has a drainage basin area of 63.5 Km^2, with 14.6 Km of stream (Figure 22). Cee Cee Ah has a diverse morphology with varied gradient. The Cee Cee Ah Creek watershed has an intermediate gradient in the headwaters, a low gradient middle of watershed and, a short high gradient section with a 25 m waterfall, and a low gradient for the last 2 Km of stream. This creek has an extensive slough system for the last 1 Km before it's confluence with the Pend Oreille River. Cee Cee Ah Creek empties into the Pend Oreille River at river kilometer 130.

Browns Creek is a major tributary of Cee Cee Ah Creek. Lower Browns Creek originats from springs fed by Browns Lake, the lower creek flows approximately 5.5 Km from the origin to the confluence with Cee Cee Ah Creek. Lower Browns Creek begins as a series of beaver ponds and runs through relatively undisturbed forests to another series of beaver ponds in the middle reach. The lower portion flows through mature forests with fairly consistent high gradient. The drainage basin area for Browns Creek is approximately 21.5 Km^2.

LeClerc Creek is the largest drainage of the three priority tributaries. LeClerc Creek's drainage basin is 161 Km^2 (Figure 23). The LeClerc system is split into three separate branches (East, West, and Middle). There are approximately 93 Km of stream in the LeClerc system. This is one of the largest tributary systems in the Box Canyon Reservoir. Major tributaries to the LeClerc system are, Mineral and Whiteman Creeks (tributaries to the West Branch of LeClerc), and Fourth of July Creek (tributary to East Branch of LeClerc Creek). The East and Middle branch flow together 5 Km above the confluence with the Pend Oreille River. The main branch is formed by the merging of the East and West branches 2.5 km above the Pend Oreille River. LeClerc Creek flows into the Pend Oreille River at approximately river kilometer 90.

Indian Creek has the smallest drainage basin of all the tributaries surveyed at 20 Km^2 and is one of the shortest tributaries with 3.8 Km of stream channel (Figure 24). This stream has no secondary tributaries and is spring fed. This stream flows through relatively low gradients and is generally wide and shallow. A series of beaver dams are constructed at the mouth of this stream creating potential migration barriers. The stream flows into the Pend Oreille River on the East side at river kilometer 140.

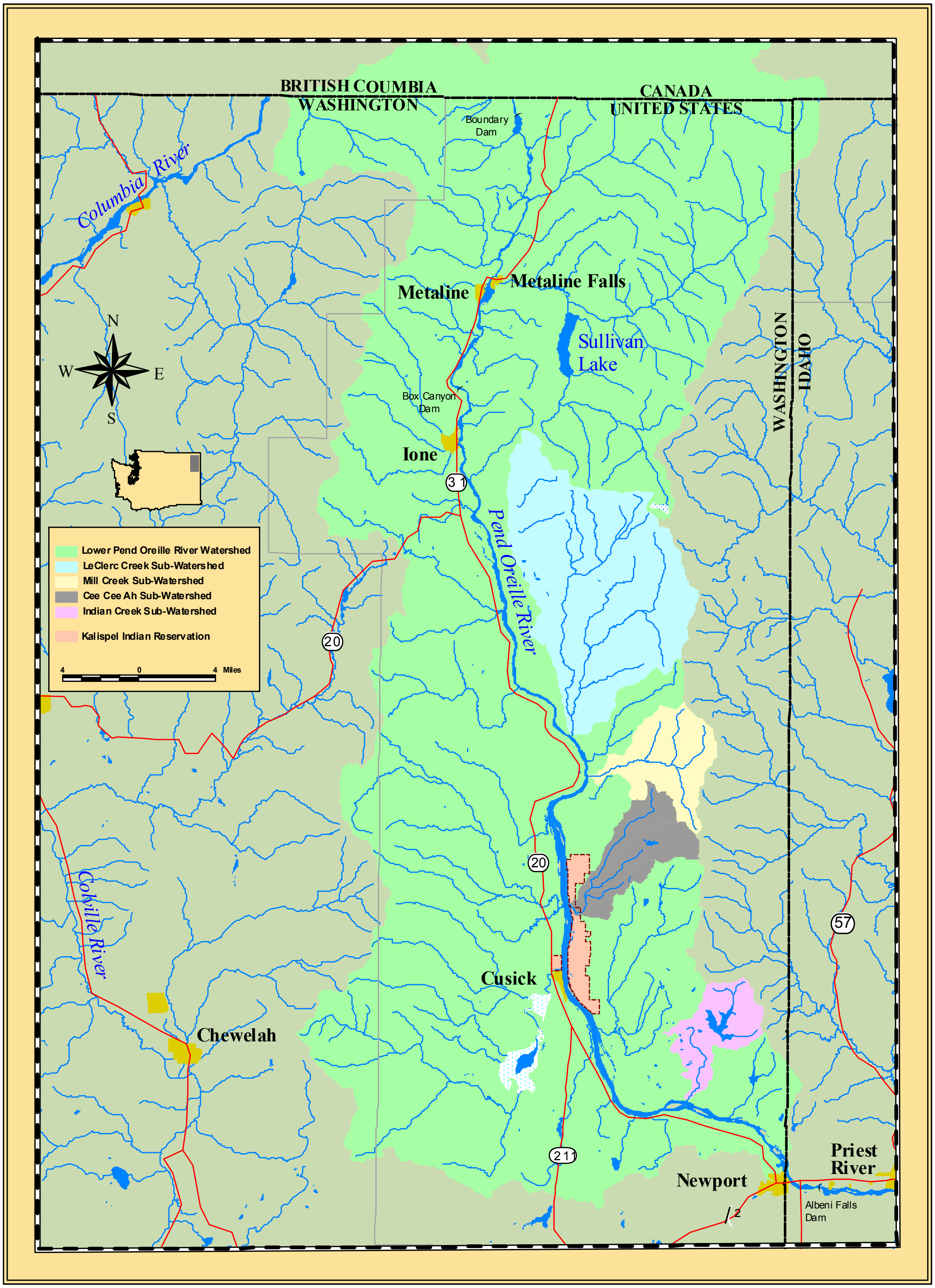

Figure 21. Map of study area including Pend Oreille River watershed and sub-watersheds where enhancement activity has been implemented.

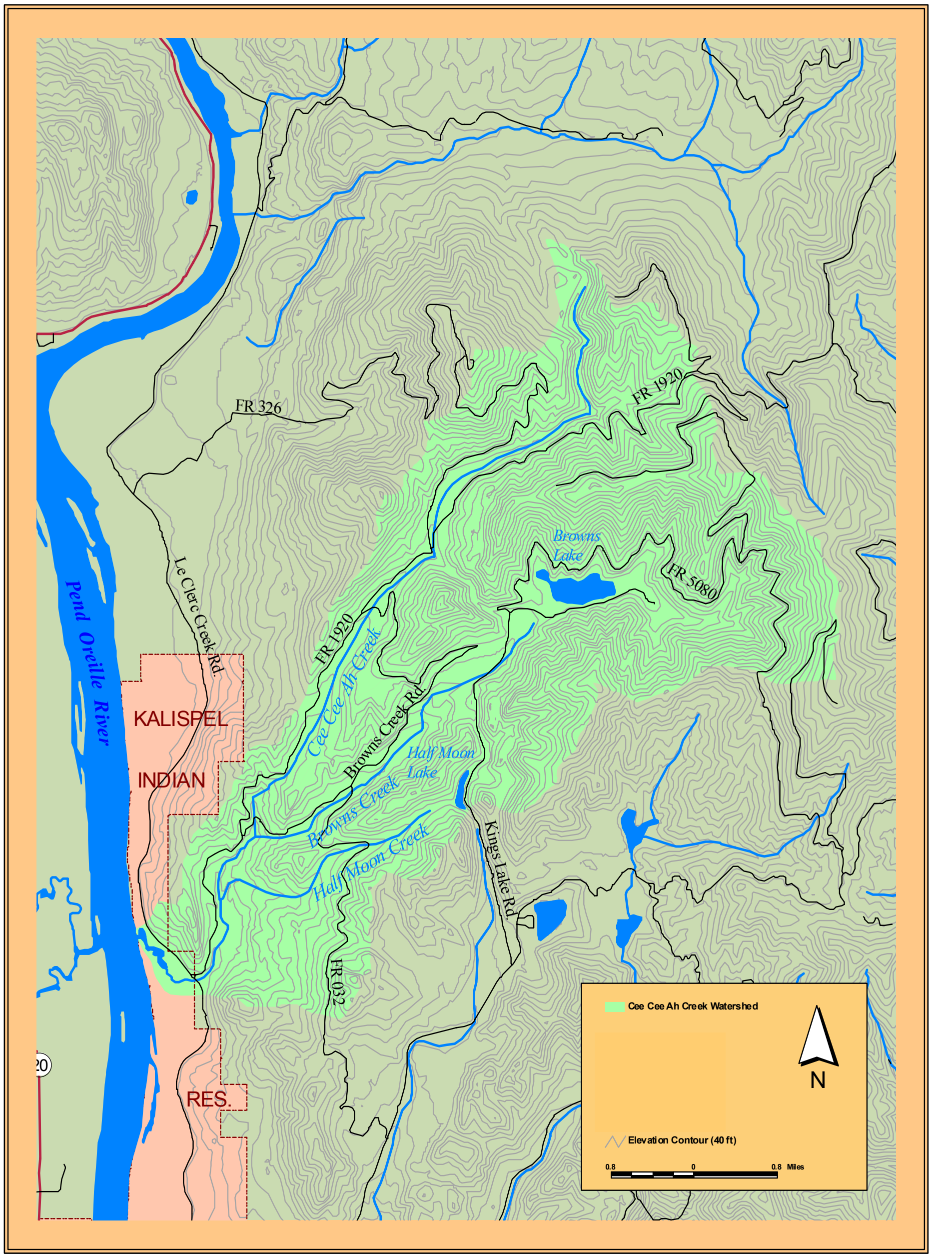

Figure 22. Map of Cee Cee Ah Creek watershed and Browns Creek sub-watershed where habitat enhancement was implemented in 1996, 1997 and 1998.

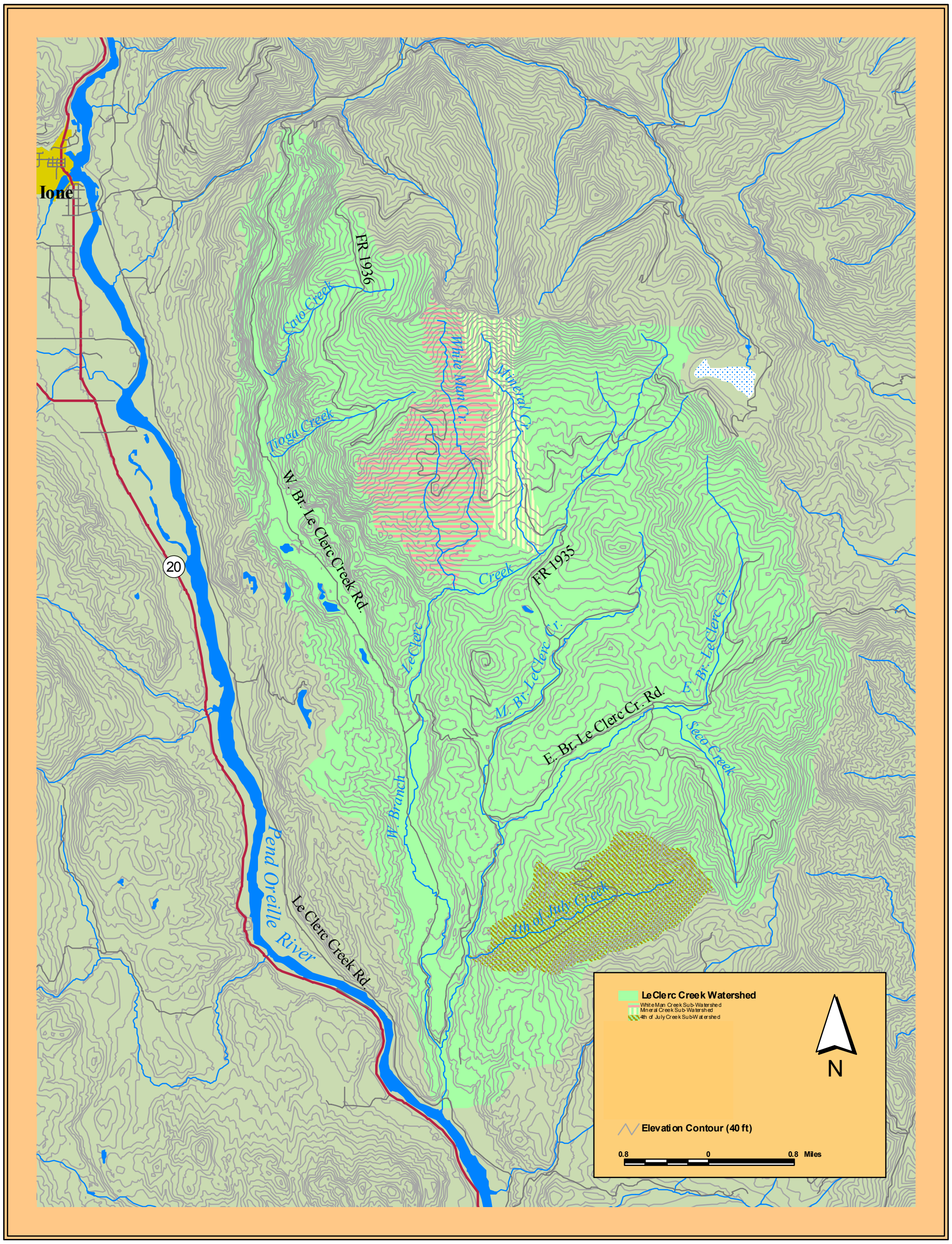

Figure 23. Map of LeClerc Creek watershed and highlighted sub-watersheds where habitat enhancement was implemented in 1996, 1997 and 1998.

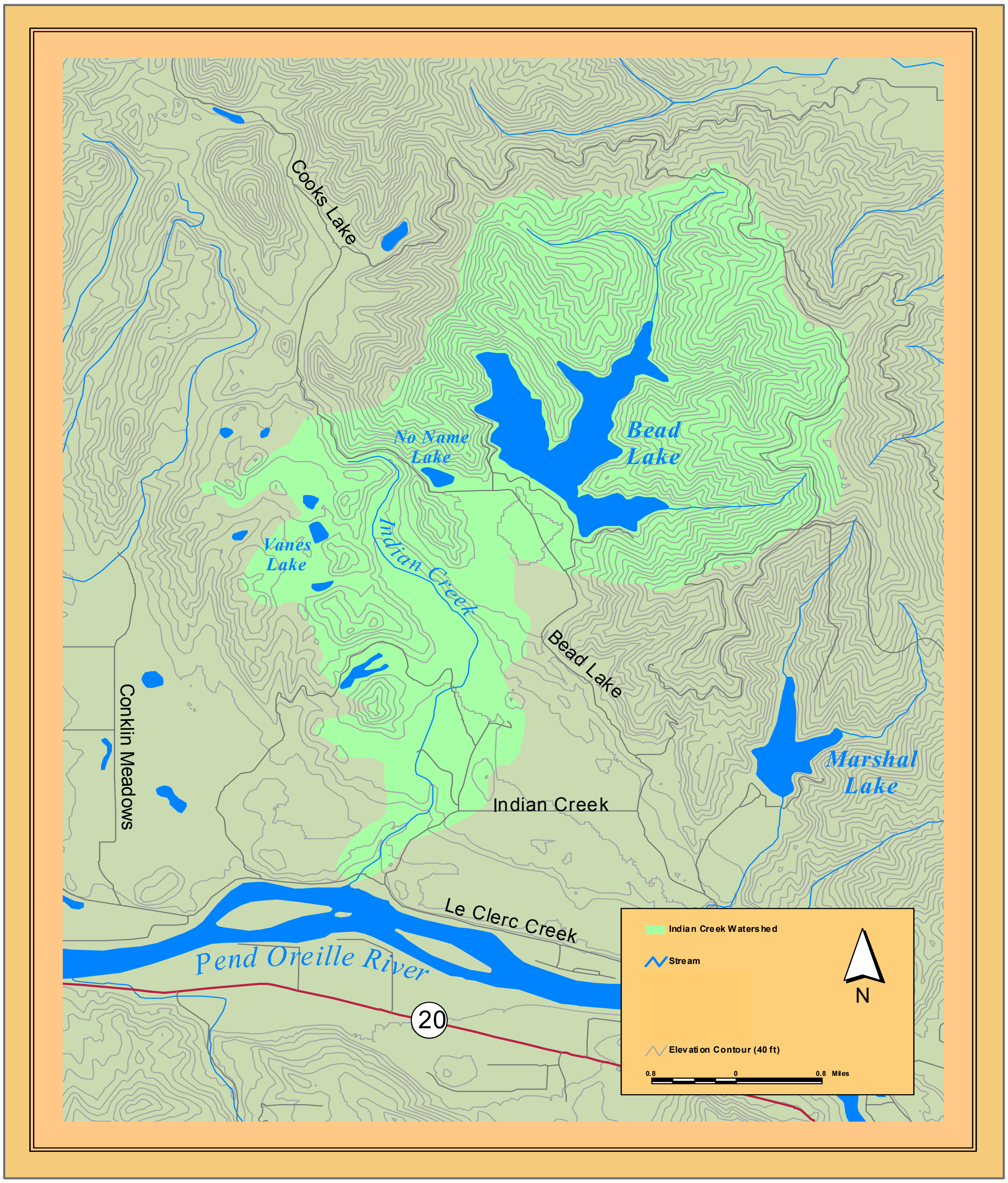

Figure 24. Map of Indian Creek watershed where habitat enhancement was implemented in 1996, 1997 and 1998.

METHODS

Baseline fish habitat data, collected in 1995, were analyzed to determine where enhancement would take place. For each surveyed stream, an inter-reach comparison was conducted using the mean attribute values for each reach. This was the fundamental unit of comparison to determine specific reaches for enhancement projects. Threshold values were established for embeddedness, bank stability, bank cover, instream cover, pool-riffle ratio, spawning gravel, and primary pools (Table 24). All threshold values were obtained from Hunter (1991) and/or MacDonald et al. (1991). The mean data for each reach was analyzed by using these threshold criteria. Each habitat value that did not fall within the threshold was counted as habitat that is unsatisfactory for quality or quantity. The reaches with the highest number of unsatisfactory habitat values were identified as potential enhancement sites for that particular stream. Snorkel surveys were used to determine fish population densities and age class distribution for all salmonid populations within each stream. Information from the snorkel surveys and the inter-reach comparisons was used to draw conclusions on the effects of degraded habitat quality and non-native salmonids on native salmonid species. Conclusions were used to aid in more informed restoration recommendations.

Data from the specific reaches identified in the inter-reach comparison was evaluated in a flowchart to provide a list of possible options for the types of structures or measures used in enhancement (Figure 25). The flow chart took into account gradient, embeddedness, and pool to riffle ratio. Each structure was designed to perform specific functions and required specific habitat placement. Structure selection was made by reviewing the list of options for enhancement and choosing the structure that addresses the limiting factors for each particular reach of enhancement. Reach accessibility was also considered when choosing between structures with similar function but varying levels of effort in their construction. Specific placement was determined by the transects within each reach that were in the habitat type for which each structure was designed.

Prior to implementation, all sites selected, as areas for enhancement were pre-assessed using an intense version of the standard transect methodology. The same methodology was used for both pre and post assessments. The only modification to the standard transect methodology was a shortening of the length between transects. Riparian project areas were assessed with 10 m transects for each kilometer where fencing and planting occurred. Instream structures were assessed using 5 m transect spacing; the assessment was conducted from 30 m above (upstream) the structure site to 30 m below (downstream).

Fish monitoring stations for riparian restoration were calculated to be one 30 m snorkel station per 250 m of stream. A minimum sample size of three snorkel stations for each restoration area was conducted, unless the area was less than or equal to 90 m long, in which case the entire area was snorkeled. Assuming the lowest known bull trout population density (0.075 bull trout/30 m) in the state of Washington (Hillman and Platts 1993), we were 95% confident that if bull trout were in the stretch of the stream we would observe them at this rate of sampling. Bull trout were used to determine the sample size because they are the least abundant native salmonid species in the area. Each monitoring station was benchmarked at the upper and lower boundary with labeled aluminum tags attached to rebar stakes. Data from snorkel stations will be used to determine densities of all fish species present.

Fish monitoring for instream structures was conducted annually to determine the fish numbers and species within the enhancement area. The stream length snorkeled, from 30 m below to 30 m above the stream section where structures were placed, was identical to where habitat monitoring occurs.

All instream structure enhancement areas were monitored annually. Riparian planting and cattle exclusion fence sites are intended to provide longer term rehabilitation over an extended time schedule. The rate of post-assessment sampling for these sites was every third year.

Post assessment data in 14 reaches were compared to pre-assessment data for structures implemented from 1996 to 1998. Comparisons were limited to the following stream survey attributes: 1) substrate embeddedness, 2) percent pool habitat, 3) average depth, 4) average width, 5) number of primary pools, and 6) spawning gravel. These survey attributes were chosen for comparison because they have the best potential to reflect short term changes in habitat that may result from the restoration structures. Also, these were the attributes identified in the baseline surveys as limiting fish populations. Since no control reaches were sampled, changes to habitat attributes were assumed to be the result of the restoration structures.

Changes to the spawning gravel assessment were made prior to the 2001 sampling season. Previous assessments of spring spawning gravel included areas that were underwater during the spring but dry at base flows (generally starting in July or August), while fall spawning gravel was evaluated at base flow conditions. In 2000, local resident cutthroat trout were observed spawning in mid July at base flows. It appears that previous fall spawning habitat assessments more accurately reflected available spring spawning habitat, as well as fall spawning habitat. Therefore, starting in 2001 evaluation of spawning habitat only considered gravels within the base flow wetted channel. Since there appears to be little local difference between the spawning habitat of spring and fall spawners, no distinction between fall and spring spawning habitat was made in 2001 and later habitat post assessments. Comparisons of 2001 and later spawning habitat data were made with previous years' fall spawning habitat since it appears to more accurately represent actual spawning habitat.

Table 24. Interreach comparison threshold values (after Hunter 1991; MacDonald 1991).

Limiting Factor	Threshold Value
Embeddedness	Any value ≥ .30 or ≤ .70
Bank Stability	Any value ≤ 75%
Bank Cover	Any value ≤ 2.5
Instream Cover	Any value ≤ 2.0
Pool - Riffle Ratio	Any value ≤ .5:1 or ≥ 1.5:1
Spawning Gravel	Three lowest cumulative values
Primary Pools	Three lowest values

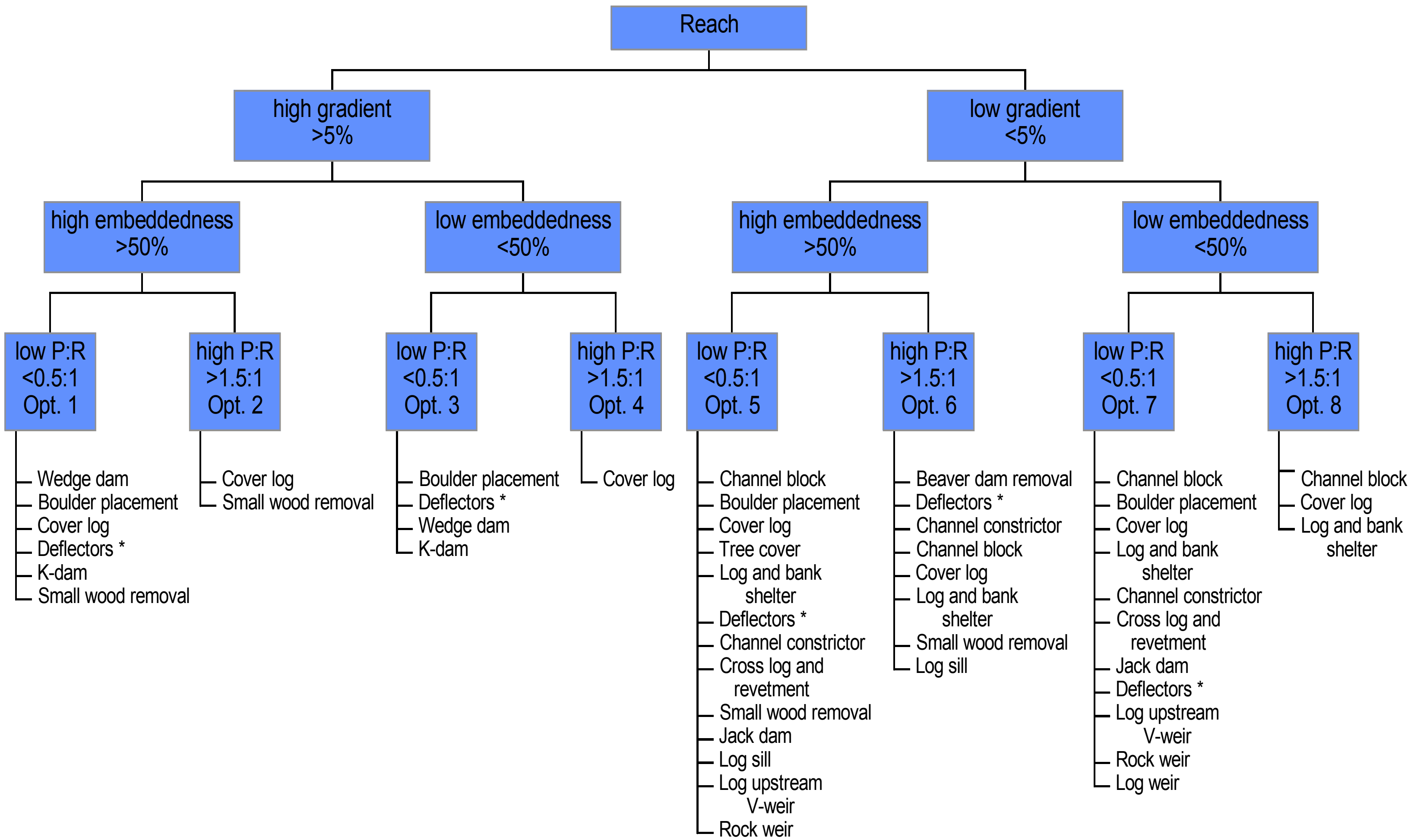

Figure 25. Flowchart for identified reaches of enhancement and the possible structures available for enhancement. Values derived after Harrelson et al. 1994, Macdonald 1991 and Hunter 1991.

RESULTS

Cee Cee Ah Creek

<u>Reach 4</u>

In 1996, three K-dams were constructed following pre-assessment. Annual trends have been variable. Embeddedness ranged from 32% in 2000 to 75.7% in 2003 (Table 25). Spawning gravel was high in the pre-assessment (8.1 m^2), but no substrate was classified as spawning gravel in 5 of the 7 years of post assessment and only 0.5 m^2 was observed in 2002. The percent of pool habitat increased from 7% in the 1996 pre-assessment to a high of 38% in 2001; however, pool composition dropped to 0% in 2003. Generally, increased average widths were observed through 2003. Primary pools increased from 2 in the 1996 pre-assessment to 5 in 1999; however, no pools were classified as primary in 2003.

In the 1997 implementation site, four K-dams were constructed following the pre-assessment. Substrate embeddedness has remained relatively constant through 2002; however, embeddedness increased to 84% in 2003 (Table 26). Spawning gravels have been absent in all of the assessments. Percent pool habitat decreased to 0% in 2003. Average depth decreased from 31.9 cm in 1997 to 15.2 cm in 2003. Average width has varied annually.

Five structures were implemented in reach 4 in 1998. Substrate embeddedness has been fairly constant through the monitoring period; pre-assessed embeddedness was 45% and 2003 embeddedness was 56% (Table 27). No spawning gravel was observed in the pre-assessment, and spawning gravel was classified in only one post assessment (0.5 m^2 in 2000). Prior to 2003, percent pool habitat has increased substantially; no habitat was classified as pool in the 1998 pre-assessment and 50% of the habitat was classified as pool in 2002, however in 2003 only 4% of the habitat was classified as pool habitat. Average depth decreased from 31.6 cm in 1998 to 17.2 cm in 2003. Average width also decreased; width was 4.5 m in the 1998 pre-assessment and 4.3 m in 2003. The number of primary pools has increased from 1 in the pre-assessment to a high of 5 in 2001; no pools were classified as primary in 2003.

Brook trout were the only fish species observed in the structures implemented in reach 4. From pre-assessment to 2003, fish densities increased in the 1997 implementation sites (Figure 26). However, after three years of decreases, fish density in the 1996 site was relatively unchanged.

Table 25. Annual Cee Cee Ah Creek reach 4 habitat attributes from the 1996 implementation site.

	96 Structures							
Attribute	Pre '96	Post '97	Post '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	48	52	38	60	32	40	40	76
Pool/Riffle	0.4	0.4	0.7	0.3	0.3	0.5	0.3	0.0
Spawning Gravel (m^2)	8.1	0.0	4.5	0.0	0.0	0.0	0.5	0
% Pool	7	5	5	19	24	38	18	0
% Riffle	65	61	50	48	69	51	65	49
% Run	11	20	26	33	5	11	16	51
% Pocketwater	15	14	19	0	0	0	0	0
% Glide	1	0	0	0	2	0	0	0
Avg Depth (cm)	12.1	24.6	30.2	21.6	19.5	20.2	21.2	15.6
Avg Width (m)	3.1	3.3	3.8	3.6	3.8	3.0	3.5	3.2
# Primary Pools	2	1	2	5	2	2	1	0

Table 26. Annual Cee Cee Ah Creek reach 4 habitat attributes from the 1997 implementation site.

	97 Structures						
Attribute	Pre '97	Post '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	48	32	45	34	44	46	84
Pool/Riffle	0.7	0.6	0.4	1.0	0.4	0.3	0.0
Spawning Gravel (m^2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% Pool	17	10	22	42	31	19	0.0
% Riffle	56	30	60	49	69	53	50
% Run	8	44	18	8	0	28	50
% Pocketwater	18	16	0	0	0	0	0
% Glide	0	0	0	0	0	0	0
Avg Depth (cm)	31.9	29.8	16.8	21.2	16.1	18.6	15.2
Avg Width (m)	3.7	4.2	3.3	3.7	3.2	3.5	3.4
# Primary Pools	0	3	1	2	5	1	0

Table 27. Annual Cee Cee Ah Creek reach 4 habitat attributes from the 1998 implementation site.

	98 Structures					
Attribute	Pre '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	45	59	43	41	42	56
Pool/Riffle	0.4	0.8	1.5	0.3	1.1	0.1
Spawning Gravel (m^2)	0.0	0.0	0.5	0.0	0.0	0.0
% Pool	0	33	51	27	50	4
% Riffle	67	35	45	59	40	43
% Run	16	32	3	14	10	53
% Pocketwater	13	0	0	0	0	0
% Glide	0	0	0	0	0	0
Avg Depth (cm)	31.6	23.8	21.2	15.5	23.6	17.2
Avg Width (m)	4.5	3.6	4.4	3.5	4.0	4.3
# Primary Pools	1	4	3	5	2	0

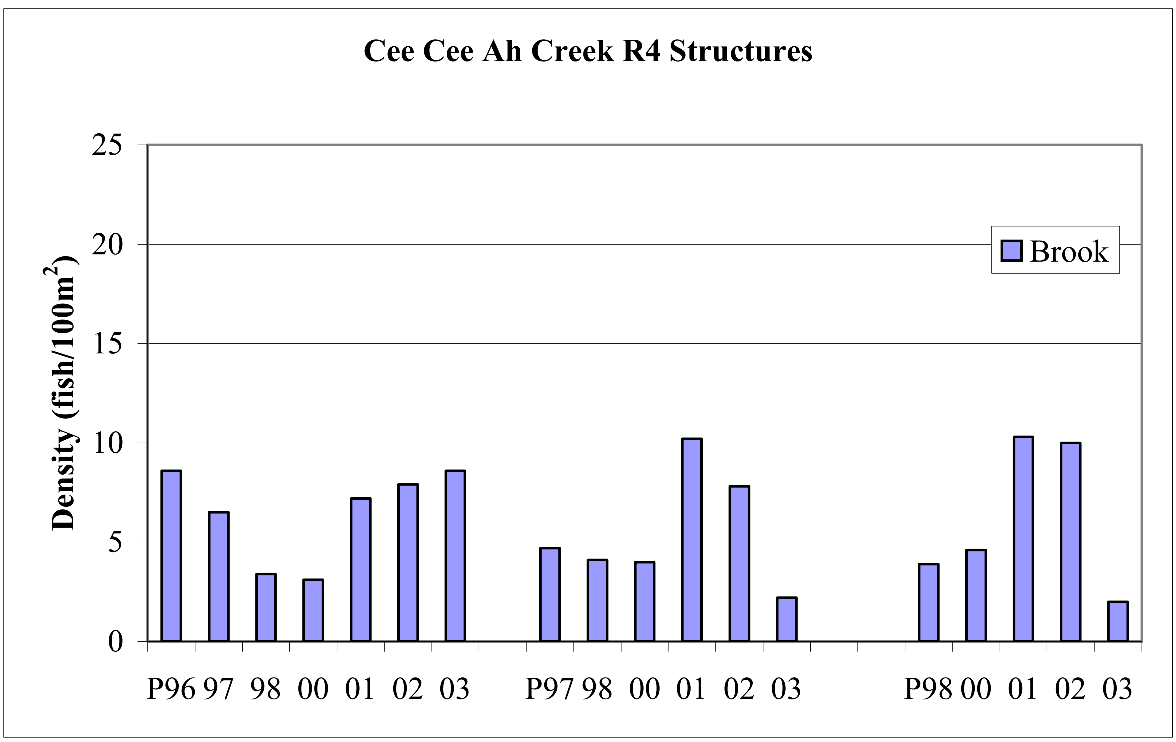

Figure 26. Annual Cee Cee Ah Creek reach 4 fish densities from the 1996, 1997, and 1998 implementation sites.

Reach 5

In reach 5, three cross log revetments were constructed in 1996 to create scour pools. Substrate embeddedness in the 1996 implementation site decreased from 77% to 36% in 2003 (Table 28). No spawning gravel was identified in the pre-assessment or in three of the post assessment years; however, 1 m^2 of spawning habitat was observed in 2003. Pool habitat was not observed in the 1996 pre-assessment; however, 57% of the habitat was classified as pool in 2003. Average depth was greater in all post assessment years except 2003 where it was at 10.5 cm. The width in 2003 (2.5 m) decreased from the pre-assessment width (3.1 m).

In the 1997 implementation site of reach 5, four cross log revetments were constructed to create scour pools. Annually, substrate embeddedness was variable but was relatively unchanged; embeddedness was 61% and 55% in the pre-assessment (1997) and in 2003, respectively (Table 29). The only spawning gravel identified in the assessments was in 2000 (1.0 m^2). Pool habitat increased from 8% in 1997 to 62% in 2003. Average depth increased from the 1997 pre-assessment (26.7 cm) to 1998 (32.4 cm); however, average depths were less in the successive years. Average widths have been annually variable. The pre-assessment primary pool number was 1; post assessment primary pool number varied annually from a high of 4 in 1999 to 2 in 1998, 2001 and 2003.

Four structures were implemented in 1998. Embeddedness decreased from 62% in the pre-assessment to 38% in 2003 (Table 30). No spawning gravels were observed in 1998, 1999, or 2001; however, 1.0 m^2 was observed in 2000 and in 2002. In 2003 1.5m^2 of spawning gravels were observed. Percent pool habitat increased from 20% in 1998 to 56% and 62% in 2003. Average depth decreased annually while average widths have been variable. One primary pool was classified in the 1998 pre-assessment and as many as 5 were identified in 2000; 3 primary pools were observed in 2003.

Post implementation brook trout densities increased in the 1996 site (Figure 27). Brook trout density increased from 6.2/100 m^2 to 20.3/100 m^2 in 2003. Cutthroat trout (n=1) were only observed at this site in 1996. For the reach 5 site implemented in 1997, brook trout density increased from 8.5/100 m^2 to 32.2/100 m^2 in 2003. Density has been variable in this site with a high of 32.2/100 m^2 in 2003 and a low of 3.8/100 m^2 in 2000. Annual variability in brook trout density has occurred in the 1998 implementation. Density declined from 14.6/100 m^2 in 1998 to a low of 7.4/100 m^2 in 2000. In 2003, brook trout density was 20.2/100 m^2.

Table 28. Cee Cee Ah Creek reach 5 habitat attribute values from the 1996 implementation site.

	96 Structures							
Attribute	Pre ‘96	Post ‘97	Post ‘98	Post ‘99	Post ‘00	Post ‘01	Post ‘02	Post ‘03
Embeddedness (%)	77	56	47	58	43	38	51	36
Pool/Riffle	0.2	0.2	0.2	0.2	0.8	0.6	0.2	1.0
Spawning Gravel (m^2)	0.0	0.0	0.0	0.5	1.0	0.0	1.5	1.0
% Pool	0	7	0	19	43	38	20	57
% Riffle	66	53	57	67	41	56	58	35
% Run	21	34	32	13	11	2	18	9
% Pocketwater	13	6	11	0	0	0	0	0
% Glide	0	0	0	0	4	4	3	0
Avg Depth (cm)	16.2	21.5	25.7	18.1	18.1	16.2	18.6	10.5
Avg Width (m)	3.1	3.2	4.0	3.2	2.6	3.3	3.0	2.5
# Primary Pools	2	3	5	2	7	5	3	3

Table 29. Cee Cee Ah Creek reach 5 habitat attribute values from the 1997 implementation site.

	97 Structures						
Attribute	Pre ‘97	Post ‘98	Post ‘99	Post ‘00	Post ‘01	Post ‘02	Post ‘03
Embeddedness (%)	61	44	62	46	27	59	55
Pool/Riffle	0.6	0.7	0.5	5.0	1.3	0.6	1.5
Spawning Gravel (m^2)	0.0	0.0	0.0	1.0	0.0	0.0	0.0
% Pool	8	7	26	80	52	43	62
% Riffle	49	18	54	11	38	57	22
% Run	30	64	19	9	0	0	0
% Pocketwater	13	8	0	0	0	0	0
% Glide	0	2	0	0	10	0	0
Avg Depth (cm)	26.7	32.4	19.2	23.0	18.2	20.1	11.5
Avg Width (m)	3.6	4.7	4.1	2.6	3.7	4.7	3.2
# Primary Pools	1	2	4	3	2	3	2

Table 30. Cee Cee Ah Creek reach 5 habitat attribute values from the 1998 implementation site.

	98 Structures					
Attribute	Pre '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	62	68	52	48	48	38
Pool/Riffle	0.3	0.7	1.5	1.0	0.5	1.5
Spawning Gravel (m^2)	0.0	0.0	1.0	0.0	1.0	1.5
% Pool	20	25	56	44	18	62
% Riffle	52	50	44	56	39	34
% Run	21	26	0	0	43	0
% Pocketwater	7	0	0	0	0	4
% Glide	0	0	0	0	0	0
Avg Depth (cm)	31.9	22.7	21.0	16.5	20.9	10.0
Avg Width (m)	4.0	4.7	3.0	4.4	3.0	2.8
# Primary Pools	1	2	5	2	1	3

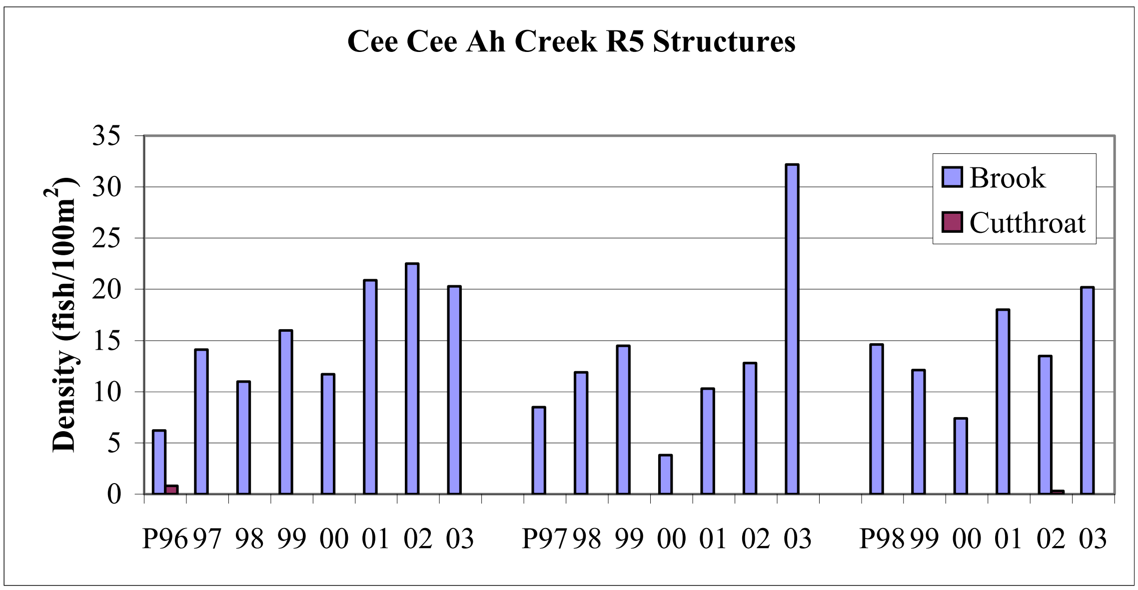

Figure 27. Annual Cee Cee Ah Creek reach 5 fish densities from the 1996, 1997, and 1998 implementation sites.

Reach 6

In 1996, three upstream v-weirs were constructed to create pool habitat and recruit spawning gravel. Substrate embeddedness in this implementation site has been variable. Pre-assessed embeddedness was 59% and 2003 embeddedness was 47% (Table 31). Spawning gravel appears to have increased, 6.4 m^2 was identified in the 1996 pre-assessment while post assessment spawning habitat was 9.5 m^2 in 2003. Pool habitat has increased in the 1996.

Table 31. Cee Cee Ah Creek reach 6 habitat attribute values from the 1996 implementation site.

	96 Structures							
Attribute	Pre '96	Post '97	Post '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	59	61	41	57	49	41	64	47
Pool/Riffle	0.2	0.5	0.7	0.7	1.0	0.9	1.0	1.1
Spawning Gravel (m^2)	6.4	0.0	0.0	1.0	1.0	0.5	3.8	9.5
% Pool	9	12	17	38	51	49	46	48
% Riffle	45	35	51	49	35	51	39	35
% Run	39	49	24	3	7	0	15	14.0
% Pocketwater	2	4	8	1	0	0	0	0
% Glide	4	0	0	8	4	0	0	0
Avg Depth (cm)	18.7	23.9	31.7	19.9	21.6	17.4	21.1	10.5
Avg Width (m)	2.5	2.9	3.2	3.2	2.6	3.0	2.9	2.5
# Primary Pools	5	4	0	4	5	4	3	5

implementation site. Pre-assessed pool habitat composition was 9% and increased to 48% in 2003. Post assessment average depths were mostly greater than the pre-assessed average depth (18.7 cm); average depth in 2003 was however, 10.5 cm. Average widths initially increased to a high of 3.2 m in 1998 and 1999; however, average width was again 2.5 m in 2003. The number of primary pools has decreased or remained unchanged over the monitoring period. 5 primary pools were identified in 1996 and 5 pools were classified as primary in 2003.

Four upstream v-weirs were constructed in reach 6 in 1997. Substrate embeddedness was 67% in 1997 (pre-assessment) and decreased to 50% in 2003 (Table 32). Spawning gravel appeared to increase; no gravel was observed in the pre-assessment while 1.0 m^2 of spawning gravel was identified in 2003. Pool habitat increased from 5% in 1997 to 60% in 2003. The pre-assessed depth was 34.3 cm in 1997 and has been less in each of the monitoring years. Average widths decreased from 3.3 m in 1997 to 2.3 m in 2003. Primary pool number initially increased from 2 in 1997 to 4 in 2000 and 2001; however, only 2 pools were classified as a primary pool in 2003.

In 1998, three structures were implemented to increase pool habitat and recruit spawning gravel. Substrate embeddedness decreased from 63% in 1998 to 50% in 2003 (Table 33). Spawning gravel appeared to increase from 0.5 m^2 in 1998 to 3.0 m^2 in 2003. No pool habitat was classified in the pre-assessment and 59% of the habitat was classified as pool in 2003. Average depth decreased from 31.1 cm in 1998 to 10.4 cm in 2003. Average width also decreased. The pre-assessed average width was 3.6 m and decreased to 2.6 m in 2003. Primary pools have increased in this site. Pre-assessed primary pool number was 1, increased to a high of 5 in 2000, 2001, and 2003.

In reach 6, brook trout densities were relatively stable (with the exception of 2000, Figure 28). 1996 pre-implementation density was 16.6/100 m^2; density remained relatively unchanged up to 2000 when 5.6/100 m^2 were observed. However, brook trout density increased to 21.7/100 m^2 in 2001 and then decreased in 2003 to 13.0/100 m^2. Brook trout density in the 1997 implementation site increased from16.6/100m^2 to 18.7/100m^2 in 2003.

Table 32. Cee Cee Ah Creek reach 6 habitat attribute values from the 1997 implementation site.

	97 Structures						
Attribute	Pre '97	Post '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	67	47	67	45	36	54	50
Pool/Riffle	0.6	0.7	0.7	1.6	0.7	1.2	1.4
Spawning Gravel (m^2)	0.0	1.0	1.5	0.0	0.0	3.0	1.0
% Pool	5	7	39	61	36	43	60
% Riffle	53	60	43	32	64	29	31
% Run	21	19	9	7	0	28	2.8
% Pocketwater	21	14	0	0	0	0	0
% Glide	0	0	8	0	0	0	0
Avg Depth (cm)	34.3	29.9	19.6	21.9	17.5	23.8	14.0
Avg Width (m)	3.3	3.5	3.3	2.5	3.4	3.3	2.3
# Primary Pools	2	2	3	4	4	1	2

Table 33. Cee Cee Ah Creek reach 6 habitat attribute values from the 1998 implementation site.

	98 Structures					
Attribute	Pre '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	63	46	45	37	45	50
Pool/Riffle	0.3	0.4	0.8	0.8	0.7	1.0
Spawning Gravel (m^2)	0.5	0.0	0.5	0.0	2.5	3.0
% Pool	0	25	48	53	37	59
% Riffle	65	58	44	47	28	36
% Run	20	5	8	0	35	2
% Pocketwater	13	0	0	0	0	0
% Glide	0	12	0	0	0	2
Avg Depth (cm)	31.1	18.4	20.6	17.2	20.1	10.4
Avg Width (m)	3.6	3.2	2.5	3.1	2.5	2.6
# Primary Pools	1	2	5	5	3	5

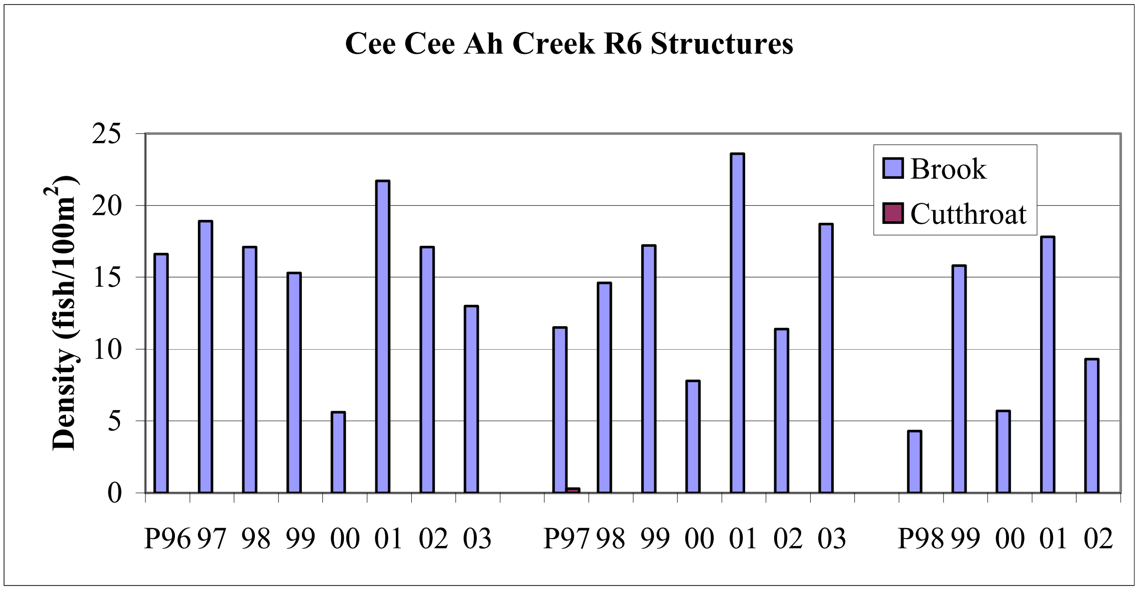

Figure 28. Annual Cee Cee Ah Creek reach 6 fish densities from the 1996, 1997, and 1998 implementation sites.

Indian Creek

Reach 3

In 1996, three double-wing deflectors were constructed in reach 3 following the pre-assessment. Post implementation substrate embeddedness in reach 3 was lower in all years of monitoring (Table 34). Pre-implementation embeddedness was 80 percent and monitoring values ranged from 76% in 2002 to 53% in 2001. Spawning gravel progressively declined from the pre-assessed estimate of 23 m^2; no spawning gravel was observed in 2001 or in 2002, and 1.0 m^2 was observed in 2003. Pool type habitat has been extremely variable. In the 1996 pre-assessment 0% of the habitat was classified as pool. Post assessment pool composition has ranged from 0% in 1997 and 1998 to 51% in 2000. Prior to 2003, average depths in monitoring years were all greater than the 1996 pre-assessment value. In 1996, the average depth was 17.9 cm and post assessments depths ranged from 22.0 cm in 2001 to 41.7 cm in 1997, however, in 2003 depth decreased to 16.5 cm. Annual average widths increased over the pre-assessed value with the lowest post assessment average width recorded in 2001. Primary pool numbers were variable; no primary pools were identified in 1996, 2002 or 2003 and up to 5 pools were observed in years between.

Fish densities in reach 3 appeared to decline from pre-assessment in 1996 to 2003 (Figure 29). Cutthroat trout were not observed in the pre-assessment or in the 2000 to 2003 period; they were initially observed in 1997 and densities decreased annually in 1998 and 1999. The brook trout density varied annually; pre-assessment density was 6.0/100 m^2, the high was 7.2/100 m^2 in 2002, and the low of 2.0/100 m^2 was observed in

2000. Brown trout density was highest during the pre-assessment (5.0/100 m^2) and 1997 was the low (0.8/100 m^2).

Table 34. Indian Creek reach 3 habitat attribute values from the 1996 implementation site.

	96 Structures							
Attribute	Pre '96	Post '97	Post '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	80	56	75	67	68	53	76	73
Pool/Riffle	0.2	0.8	0.6	0.5	2.0	1.0	0.1	0.2
Spawning Gravel (m^2)	23.0	14.0	9.0	1.5	0.5	0.0	0.0	1.0
% Pool	0	0	0	5	51	50	4	16
% Riffle	64	33	35	25	27	48	32	64
% Run	26	47	56	66	19	2	64	20
% Pocketwater	7	19	9	3	0	0	0	0
% Glide	2	0	0	0	2	0	0	0
Avg Depth (cm)	17.9	41.7	29.1	38.3	26.7	22.0	22.3	16.5
Avg Width (m)	2.9	4.8	5.0	4.7	4.3	4.2	4.3	4.2
# Primary Pools	0	2	0	1	5	3	0	0

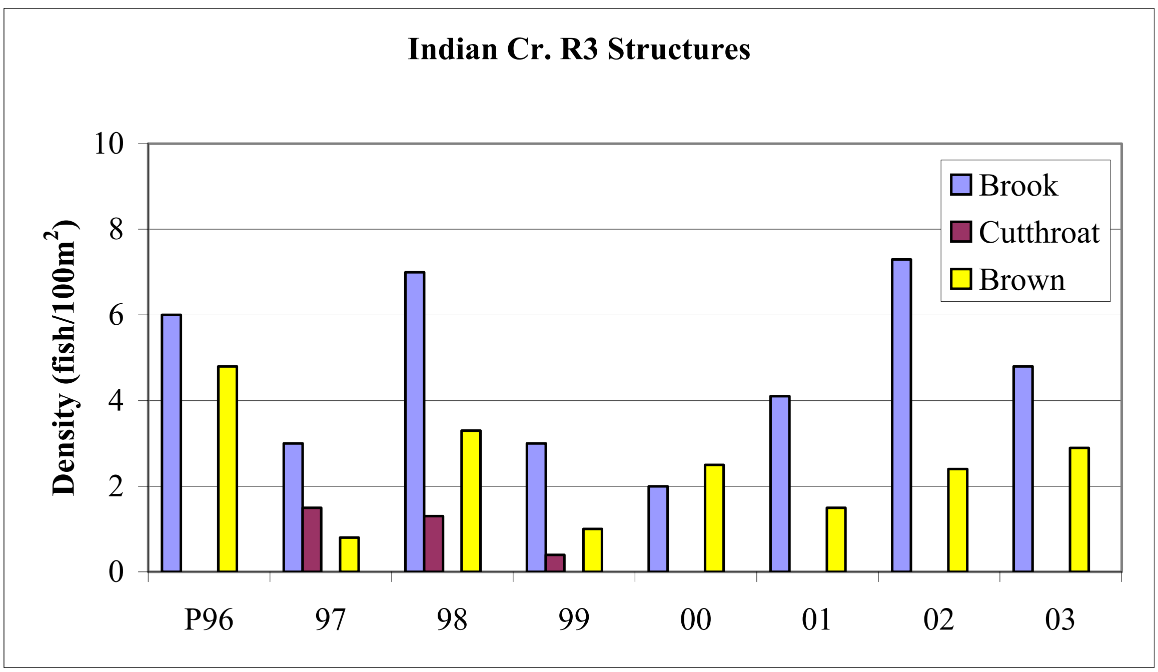

Figure 29. Annual Indian Creek reach 3 fish densities from the 1996 implementation site.

Table 35. Indian Creek reach 4 habitat attribute values from the 1996 implementation site.

	96 Structures							
Attribute	Pre ‘96	Post ‘97	Post ‘98	Post ‘99	Post ‘00	Post ‘01	Post ‘02	Post ‘03
Embeddedness (%)	82	16	33	50	38	33	45	66
Pool/Riffle	0.1	0.2	0.1	0.0	0.3	0.3	0.1	0.0
Spawning Gravel (m^2)	9.0	5.5	10.0	2.5	1.5	4.0	19.5	0.0
% Pool	0	4	2	1	15	23	5	0
% Riffle	85	82	90	94	80	77	82	80
% Run	8	4	1	5	0	0	9	20
% Pocketwater	6	10	7	0	4	0	4	0
% Glide	0	0	0	0	1	0	0	0
Avg Depth (cm)	10.9	28.7	22.1	26.5	19.8	17.7	16.9	12.6
Avg Width (m)	2.1	4.3	4.2	4.2	3.8	3.7	3.6	3.9
# Primary Pools	0	3	0	0	3	4	0	0

Reach 4

In reach 4, three log weirs were constructed to provide scour pools and recruit spawning gravel. Substrate embeddedness decreased from a 1996 pre-assessed value of 82% to 66% in 2003 (Table 35). Spawning habitat has been variable throughout the monitoring period. In 1996, pre-assessed spawning gravel was estimated at 9.0 m^2, monitoring estimates ranged from 0 m^2 in 2003 to 19.5 m^2 in 2002. No pool type habitat was classified in the pre-assessment survey in 1996. Pool habitat has been variable with a range of 23% in 2001 to 0% in 2003, however, run-type habitat increased from 8% to 20% in 2003. Average widths and depths increased in years following the pre-assessment. The pre-assessed average depth was 10.9 cm; in subsequent monitoring years, average depths ranged from 12.6 cm in 2003 to 28.7 cm in 1997. The pre-assessed average width was 2.1 m; post assessment average widths increased to 3.9 m by 2003. Primary pool numbers have been variable; 4 primary pools were identified in 2001 but no pools were observed in 2002, or 2003.

Changes to fish densities in reach 4 were variable (Figure 30). Cutthroat density increased over 300% from 1996 to 2000. However, no cutthroat trout were observed from 2001 to 2003. The highest densities of brook and brown trout occurred in 2001 at 6.1/100 m^2 and 5.5/100 m^2, respectively.

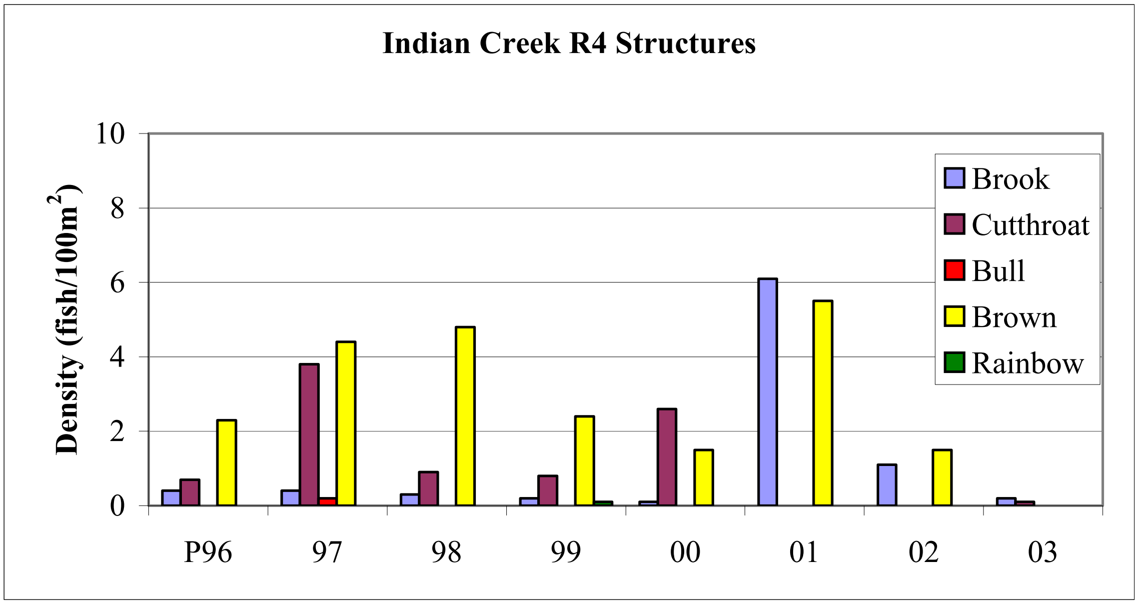

Figure 30. Annual Indian Creek reach 4 fish densities from the 1996 implementation site.

Browns Creek

Reach 4

Three K-dams were constructed in reach 4 in 1997. Pre-assessed substrate embeddedness was 31% and increased to 90% in 2003 (Table 36). Spawning gravels in monitoring years appeared to decrease markedly over pre-assessed estimates. 1997 pre-assessed spawning gravel was estimated at 12.5 m^2; no gravel was classified as spawning habitat in the 2003 post assessment. The percent of pre-assessed habitat classified as pool was 3% and showed increases every year through 2001. In 2002, no pool habitat was identified; however, all of the slow water habitat was classified as run (24%). Average depth decreased from 25.7 cm in 1997 to 16.3 cm in 2003. In 2002, wetted width was unchanged from a pre-assessed average of 4.9 m. In the 1998 post assessment, surveyors classified three pools as primary pools. No primary pools were observed in 2003.

Three additional structures were built in reach 4 in 1998. Embeddedness in this site increased from 28% in the pre-assessment to 53% in 2002 (Table 37). Pre-assessed spawning gravel was 4.5 m^2; no spawning gravel was observed in 2003. Slow water habitat types have increased in this restoration reach. No habitat was classified as pool in the 1998 pre-assessment and the 1999 post assessment. However, up to 33% of the habitat was classified as pool since that time and runs have increased from 2% to 32%. Average depths decreased annually to a low of 15.4 cm in 2001 and then increased to 18 cm in 2003. Average width has been highly variable. The pre-assessed width was 4.0 m; post assessment widths ranged from 3.9 m in 2001 to 7.2 m in 1999. No pools were classified as primary during the pre-assessment in 1998 nor in 2003.

In the 1997 implementation site, brown trout densities increased from 4.2/100 m^2 in 1997 to 9.2/100 m^2 in 2001 (Figure 31). However, density decreased to 4.1/100 m^2 in

2003. Pre-assessment brook trout density was 0.2/100 m^2 and increased to 0.7/100 m^2 in 2002. However no brook trout were observed in 2003. The first cutthroat trout were sighted in 2003 at a density of 0.1/100 m^2. Brown trout increased from 4.1/100 m^2 in 1998 to 5.0/100 m^2 in 2003. Prior to 2003 only one cutthroat trout was observed in reach 4 and that fish was seen during the 1998 pre-assessment. In 2003 cutthroat were observed again at a density of 0.4/100 m^2.

Table 36. Browns Creek reach 4 habitat attribute values from the 1997 implementation site.

	97 Structures						
Attribute	Pre '97	Post '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	31	41	47		29	49	90
Pool/Riffle	0.1	0.3	0.1	0.3	0.2	0.0	0.0
Spawning Gravel (m^2)	12.5	4.5	0.0	1.5	0.0	0.0	0.0
% Pool	3	6	3	19	17	0	0
% Riffle	88	76	84	79	75	76	84
% Run	2	9	13	3	3	24	16
% Pocketwater	6	9	0	0	0	0	0
% Glide	0	0	0	0	5	0	0
Avg Depth (cm)	25.7	22.4	24.2	19.7	13.1	17.8	16.3
Avg Width (m)	4.9	5.2	4.7	4.1	4.8	4.9	4.5
# Primary Pools	0	3	0	0	1	1	0

Table 37. Browns Creek reach 4 habitat attribute values from the 1998 implementation site.

	98 Structures					
Attribute	Pre '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	28	52	41	29	53	64
Pool/Riffle	0.0	0.0	0.5	0.1	0.1	0.0
Spawning Gravel (m^2)	4.5	0.0	3.0	0.0	0.0	0.0
% Pool	0	0	33	9	6	4
% Riffle	92	87	67	80	66	64
% Run	2	12	0	11	28	32
% Pocketwater	5	1	0	0	0	0
% Glide	0	0	0	0	0	0
Avg Depth (cm)	26.5	26.2	19.8	15.4	19.9	18.0
Avg Width (m)	4.0	7.2	3.9	3.9	4.3	4.2
# Primary Pools	0	0	2	4	0	0

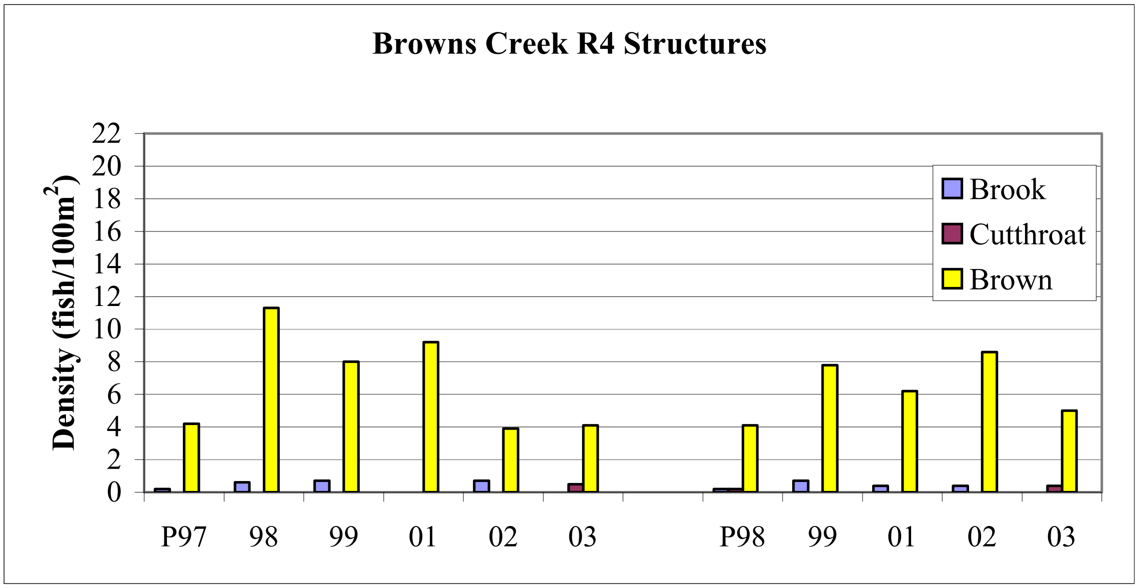

Figure 31. Annual Browns Creek reach 4 fish densities from the 1997 and 1998 implementation site.

Fourth of July Creek

Reach 8

In 1997, three wedge dams and three log weirs were constructed. 1997 pre-assessment substrate embeddedness was 82% (Table 38). Lower embeddedness values were observed in subsequent years of monitoring and decreased to 40% in 2003. Spawning gravels increased from 9.0 m^2 in 1997 to 10.0 m^2 in 1998. However, no spawning gravel was identified during the 1999, 2002 or 2003 monitoring survey and only 0.5 m^2 was observed in 2000 and 2001. No habitat was classified as pool in 1997 and 1998. However, pool composition has increased to a high of 36 % in 2001. Average depth increased from 12.5 cm in 1997 to 16.0 cm in 1998, but has decreased in succeeding years to 11.4 cm in 2003. No primary pools were identified in the 1997 pre-assessment. Surveyors counted one primary pool in 1999 and 6 in the 2000 and 2001, but no primary pools were observed in the 2003 post assessments.

Cutthroat trout (8.0/100 m^2) and brook trout (3.0/100 m^2) were observed in the 1997 pre-implementation snorkel survey (Figure 32). Bull trout were at low densities in 1998 and 1999.observed in 1999. In 2003 cutthroat trout and brook trout densities (0.9 and 2.7/100m^2, respectively) were nearly half the 1997 pre-implementation densities.

Table 38. Fourth of July Creek reach 8 habitat attribute values from the 1997 implementation site.

	97 Structures						
Attribute	Pre '97	Post '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	82	60	71	20	53	70	40
Pool/Riffle	0.1	0.4	0.3	0.5	0.6	0.2	0.0
Spawning Gravel (m^2)	9.0	10.0	0.0	0.5	0.5	0.0	0.0
% Pool	0	0	12	32	36	12	0
% Riffle	85	59	51	61	61	67	82
% Run	8	19	37	3	0	8	18
% Pocketwater	6	21	0	1	3	13	0
% Glide	0	0	0	0	0	0	0
Avg Depth (cm)	12.5	16.0	14.2	11.8	11.3	10.8	11.4
Avg Width (m)	2.4	3.0	2.3	1.9	1.8	1.8	2.4
# Primary Pools	0	0	1	6	6	0	0

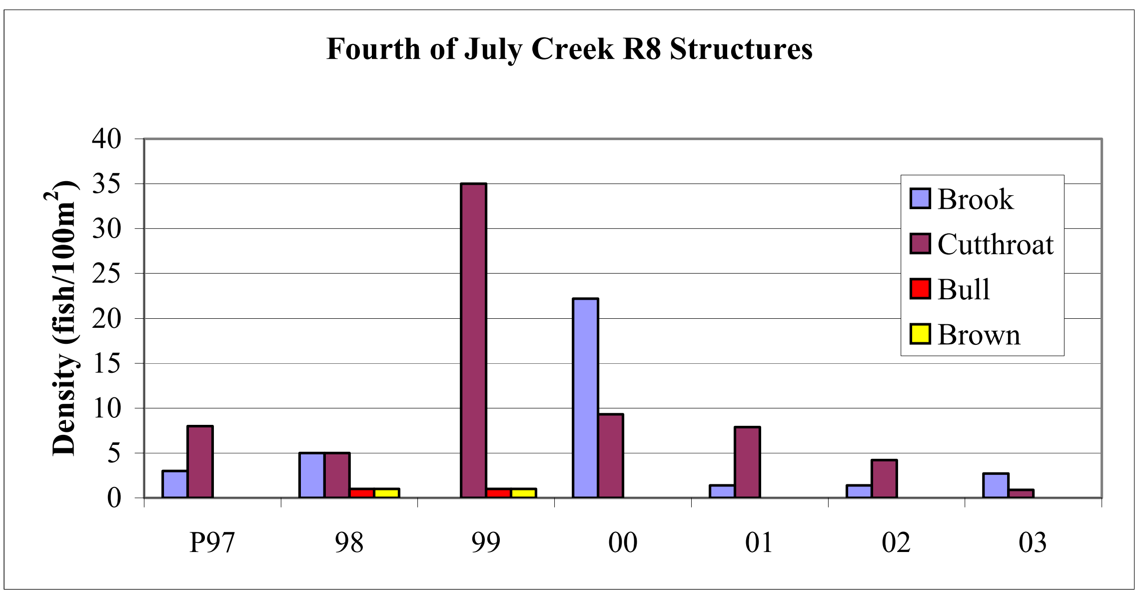

Figure 32. Annual Fourth of July Creek reach 8 fish densities from the 1997 implementation site.

Mineral Creek

Reach 1

A total of ten double wing deflectors were implemented from 1996 to 1998. Pre-assessment substrate embeddedness was 53% in the 1996 site, and has been annually variable with a high of 70% in 2003 and a low of 32% in 2001 (Table 39). 1996 pre-assessed spawning gravel was 15.3 m^2. Gravel was classified as spawning habitat in only one post assessment survey (2000 with 0.5 m^2). Percent pool type habitat increased from 4% in 1996 to 9% in 2003. The 1996 pre-assessed average depth was 16.4 cm, the greatest depth was 25.3 cm in 1999 and the lowest average depth was 12.1 cm in 2001. The average pre-assessment width was 2.6 m and the 2002 width was 3.3 m. Four pools were classified as primary during the 1996 pre-assessment and decreased to 0 pools in the 2003 post assessment.

Where structures were implemented in 1997, pre-assessed substrate embeddedness was 71% and showed a slight declined to 68% in 2003 (Table 40). Spawning gravel increased from 1.0 m^2 in the 1997 pre-assessment to a high of 4-5m^2 in 2000; however, no gravel was classified as spawning habitat in 2002 or 2003. Percent pool habitat has been variable with a range of 4% in 2003 to 43% in 2000. Depths decreased from the pre-assessed average of 43.6 cm in 1997 to 13.1 in 2003. Average width also decreased; the pre-assessed width averaged 3.5 m and width was 2.9 m in the 2003 post assessment. The number of pools classified as primary has been annually variable. Two primary pools were present in the pre-assessment while no pools were classified as primary in 2002 and 2003.

Pre assessment embeddedness in the 1998 restoration site was 54%. Embeddedness increased in 2003 to 61% (Table 41). Spawning gravel decreased from 1.0 m^2 in the pre-assessment, to 0 in the 2003 the post assessment. Percent pool type habitat increased from 15% in 1998 to 49% in 2002, however no pool habitat was observed in 2003. Average depth and width decreased in 2003 relative to 1998 pre-assessment values. Average depth decreased from 34.0 cm to 10.2 cm, while average width decreased from 3.6 m to 2.5 m. No primary pools were identified in the pre-assessment, 2 pools were observed in the 2002 post assessment but no primary pools were observed in 2003.

Generally, cutthroat trout have declined in the Mineral Creek structures while brook trout densities have increased. For the 1996 implemented structures, post assessment cutthroat trout densities have declined from pre-assessment densities (Figure 33). The 1996 brook trout density was 6.0/100 m^2 and increased to 10.8/100 m^2 in 2002, however, electrofishing removal efforts resulted in a decline in the brook trout density in 2003. Pre-assessed cutthroat density was 14.0/100 m^2 and declined to 7/100 m^2 in 2003. Fish densities in the 1997 implementation site showed a declining trend. Cutthroat density in the 1998 restoration site showed an initial increasing trend, however, cutthroat trout density declined in 2002; the pre-assessed density was 5.0/100 m^2 and the 2002 density was 5.2/100 m^2. Brook trout density has increased in the 1998 implementation site. No brook trout were observed in the 1998 pre-assessment and density has increased annually to 5.2/100 m^2 in 2002.

Table 39. Mineral Creek reach 1 habitat attribute values from the 1996 implementation site.

	96 Structures							
Attribute	Pre '96	Post '97	Post '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	53	35	45		61	32	50	70
Pool/Riffle	0.5	0.3	0.6	0.1	0.8	0.5	0.2	0.1
Spawning Gravel (m^2)	15.3	0.0	0.0	0.0	0.5	0.0	0.0	0.0
% Pool	4	0	21	4	32	14	16	9
% Riffle	61	67	57	92	52	65	75	61
% Run	16	21	3	3	0	3	9	23
% Pocketwater	19	12	19	1	12	15	0	0
% Glide	1	0	0	0	4	3	0	0
Avg Depth (cm)	16.4	19.0	23.7	25.3	14.4	13.4	20.8	12.1
Avg Width (m)	2.6	2.9	3.4	3.7	2.5	2.8	3.3	2.6
# Primary Pools	4	0	2	0	3	4	2	0

Table 40. Mineral Creek reach 1 habitat attribute values from the 1997 implementation site.

	97 Structures						
Attribute	Pre '97	Post '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	71	62	52	69	46	58	68
Pool/Riffle	0.3	0.8	0.1	0.6	0.2	0.1	0.0
Spawning Gravel (m^2)	1.0	0.0	0.0	4.5	2.5	0.0	0.0
% Pool	19	24	10	43	26	8	5
% Riffle	62	50	48	40	71	49	69
% Run	13	16	42	0	0	43	26
% Pocketwater	5	9	0	0	0	0	0
% Glide	0	0	0	17	3	0	0
Avg Depth (cm)	43.6	25.6	31.1	15.0	13.2	18.0	13.1
Avg Width (m)	3.5	2.9	3.4	2.6	2.4	3.2	2.9
# Primary Pools	2	1	2	3	2	0	0

Table 41. Mineral Creek reach 1 habitat attribute values from the 1998 implementation site.

	98 Structures					
Attribute	Pre '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	54		64	36	53	61
Pool/Riffle	0.3	0.6	0.8	1.1	1.0	0.0
Spawning Gravel (m^2)	1.0	0.0	1.0	1.0	0.0	0.0
% Pool	15	17	33	48	49	0
% Riffle	71	57	52	46	33	100
% Run	5	23	0	6	18	0
% Pocketwater	6	3	14	0	0	0
% Glide	0	0	0	0	0	0
Avg Depth (cm)	34.0	34.4	15.2	21.4	23.2	10.2
Avg Width (m)	3.6	3.6	2.1	2.8	3.0	2.5
# Primary Pools	0	0	1	4	2	0

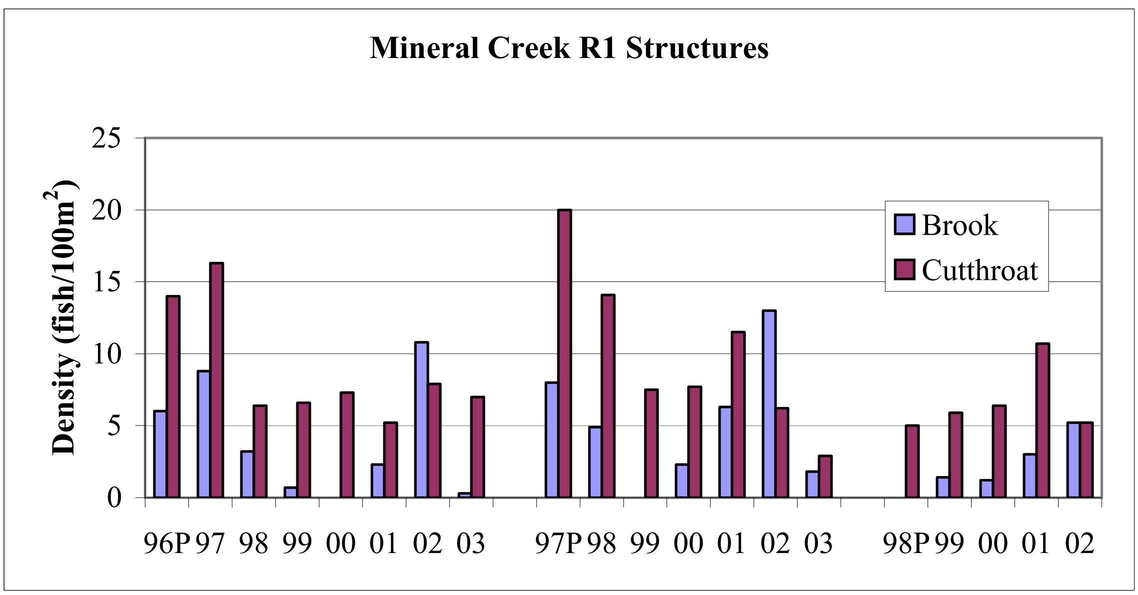

Figure 33. Annual Mineral Creek reach 1 fish densities from the 1996, 1997 and 1998 implementation sites.

Whiteman Creek

Reach 5

In 1996, boulder structures were placed in reach 5 to create pool habitat. Percent embeddedness has been variable with a high of 67% in 1997 to a low of 34% in 2001 (Table 42). Spawning gravel was absent from the assessment area for all years except in 2001 where 0.5 m^2 of gravel was classified as spawning habitat. Pool habitat increased from 7% in 1996 to 24% in 2003. The pre-assessed average depth was 13.3 cm; post assessed average depths ranged from 12.8 cm in 2003 to 24.5 cm in 2002. Average widths also increased from the pre-assessed width of 2.6 m. Average width ranged from 3.0 m in 2003 to 4.7 in 1998. The number of primary pools increased from 0 in 1996 to a high of 8 in 1999. However, no primary pools were observed in 2003.

In reach 5, cutthroat densities were relatively low and unchanged through 1999 (Figure 34). Cutthroat density in the pre-assessment was 0.5/100 m^2. The cutthroat density increased to 1.2/100 m^2 in 2000 and 2.0/100 m^2 in 2001. However, no cutthroat trout were observed in 2002. Cutthroat trout were again observed in 2003 at a density of 0.8/100m^2. Brook trout densities in reach 5 have increased from a pre-implementation density of 6.0/100 m^2 in 1996 to 13.9/100 m^2 in 2003.

Table 42. Whiteman Creek reach 5 habitat attribute values from the 1996 implementation site.

	96 Structures							
Attribute	Pre '96	Post '97	Post '98	Post '99	Post '00	Post '01	Post '02	Post '03
Embeddedness (%)	54	67	47	49	48	34	58	60
Pool/Riffle	0.2	0.4	0.5	0.6	1.1	1.8	0.8	0.2
Spawning Gravel (m^2)	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
% Pool	7	0	24	21	39	50	42	24
% Riffle	82	61	57	57	43	33	35	76
% Run	6	10	15	11	2	0	23	0
% Pocketwater	6	29	4	11	15	14	0	0
% Glide	0	0	0	0	0	3	0	0
Avg Depth (cm)	13.3	21.5	19.9	17.5	15.5	15.6	24.5	12.8
Avg Width (m)	2.6	4.1	4.7	3.5	3.3	3.6	3.7	3.0
# Primary Pools	0	1	1	8	2	4	3	0

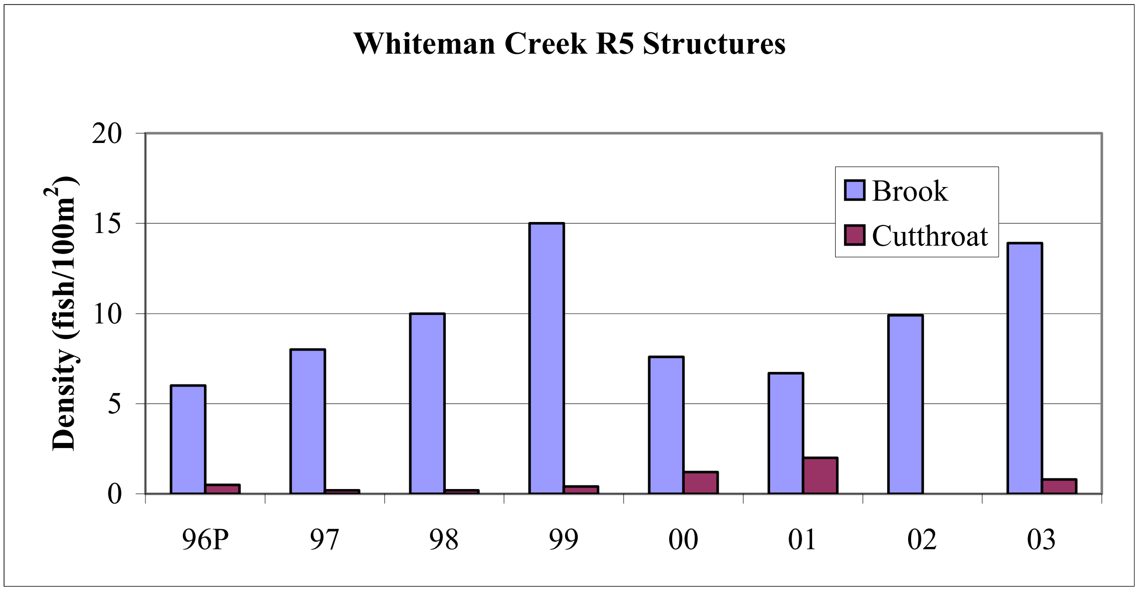

Figure 34. Annual Whiteman Creek reach 5 fish densities from the 1996 implementation site.

Reach 6

Boulder structures were placed to create pool habitat. Post assessment substrate embeddedness decreased from the pre-assessed embeddedness of 73% (Table 43). Post assessed embeddedness ranged from a low of 29% in 2001 to a high of 67% in 2003. 2.0 m^2 of spawning habitat was observed in the pre-assessment. Spawning substrate increased to 4.5 m^2 in 1997 and 2.5 m^2 in 1998. However, no spawning gravel was identified in 2003. Pool habitat increased annually from 0% in the 1996 pre-assessment to 46% in the 2001 post assessment. However, pool composition dropped in 2003 to 3%. Pre-assessed (1996) average depth was 23.4 cm and increased to 27.5 cm in 1997. Average depths decreased in subsequent years and ranged from 11.1 cm in 2003 to 18.8 cm in 2001. Average widths increased in the first two years of post assessment. The pre-assessed width was 3.8 m; width increased to 4.6 m in 1997 and 6.4 m in 1998. However, average widths from 1999 to 2003 have been less than the pre-assessed value. No primary pools were observed in the 1996 pre-assessment. Primary pool number increased to a high of 3 in 2000 and 2001; however, no primary pools were identified in 2002 or 2003.

Cutthroat densities in reach 6 have increased from the 1996 pre-assessed density of 0.5/100 m^2 to 1.1/100 m^2 in 2003 (Figure 35). Post assessed brook trout densities were variable. The 1996 pre-assessed brook trout density was 14.0/100 m^2; density ranged from 7.7/100m^2 in 2000 to 17.0/100m^2 in 1999. Brook trout density was 10.7/100 m^2 in 2003.

Table 43. Whiteman Creek reach 6 habitat attribute values from the 1996 implementation site.

	96 Structures							
Attribute	Pre ‘96	Post ‘97	Post ‘98	Post ‘99	Post ‘00	Post ‘01	Post ‘02	Post ‘03
Embeddedness (%)	73	55	38	60	55	29	48	67
Pool/Riffle	0.3	0.4	0.1	0.8	0.9	1.1	0.1	0.0
Spawning Gravel (m^2)	2.0	4.5	2.5	0.0	0.0	1.5	0.0	0.0
% Pool	0	4	4	32	38	46	5	3
% Riffle	73	51	83	51	54	46	79	97
% Run	12	30	10	3	0	0	16	0
% Pocketwater	14	15	3	14	7	6	0	0
% Glide	0	0	0	0	0	2	0	0
Avg Depth (cm)	23.4	27.5	18.5	14.3	15.6	18.8	17.2	11.1
Avg Width (m)	3.8	4.6	6.4	3.2	2.7	3.3	3.6	3.1
# Primary Pools	0	0	0	2	3	3	0	0

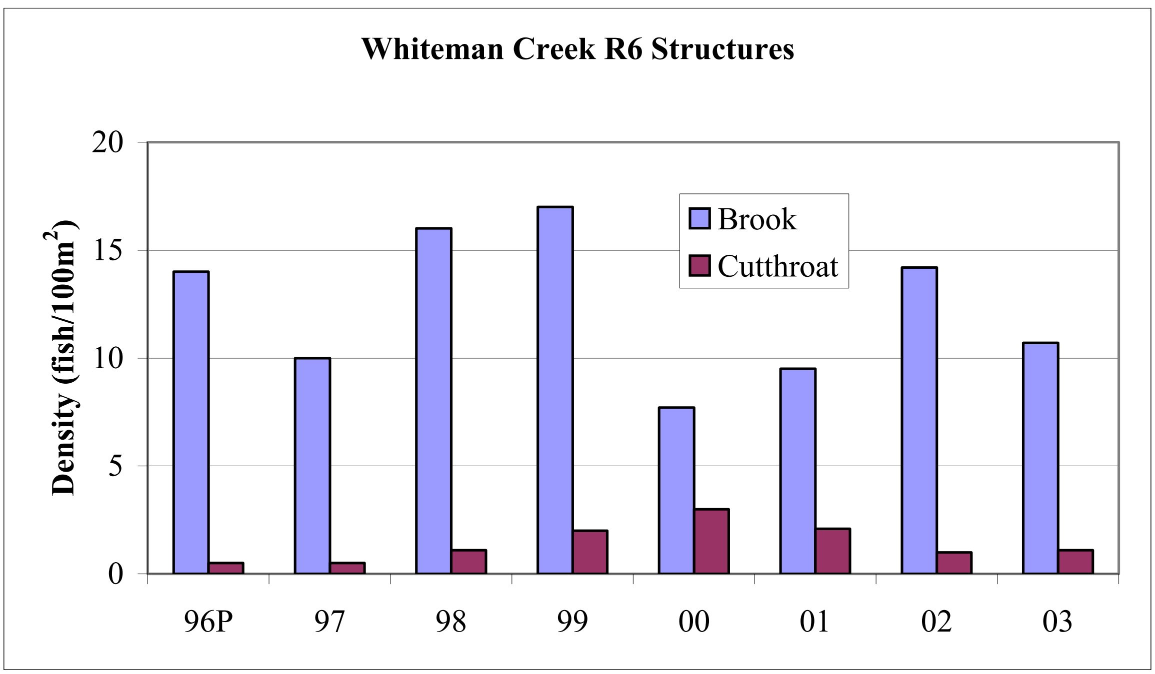

Figure 35. Annual Whiteman Creek reach 6 fish densities from the 1996 implementation site.

DISCUSSION

Results from baseline surveys of area streams conducted in 1995 and 1996 showed a general trend: large woody debris densities were relatively low and substrate embeddedness was high. LWD is a primary component of stream channel complexity. Woody debris provides many important functions to fish populations and stream channels. Wood has a critical role in modifying and maintaining channel morphology (Bisson et al. 1987; Ralph et al. 1994; Ruediger and Ward 1996), trapping transported sediment (Beschta 1979; Bilby 1984, Bilby and Ward 1989) and stabilizing stream banks. Large wood provides yearlong cover and is used as refugia during extreme flow events (Pearsons et al. 1992). Jakober et al (1998) found bull trout and cutthroat trout preferred habitat with large woody debris. Fausch and Northcote (1992) found a positive relationship between cutthroat trout abundance and habitat complexity in a small stream. High substrate embeddedness decreases the amount of cover available to overwintering fish (Griffith and Smith 1993). Increased fine sediment in streams can also fill in pools, backwater habitat, and side channels that are important to rearing and overwintering bull trout and cutthroat trout.

Fish managers often enhance habitat to increase those attributes thought to be limiting abundance or growth of a fish population. However, population responses to habitat enhancement are poorly understood and, consequently, success of these projects has been variable. Riley and Fausch (1995) detected increased abundance of adult brook trout after implementing enhancement in six Colorado streams; however, responses of age 1+ brook trout were variable. Furthermore, growth and survival of fish in the enhanced sections differed little from fish in the control section.

Difficulty arises when trying to distinguish the effects of restoration among the many interacting factors and great natural variability within the physical and biological components of the ecosystem. Aside from catastrophic events, stream processes are generally slow and diminutive. Therefore, much of the restoration implemented may not yield measurable results for several years or decades (Heede 1986, Hunt 1976).

Observer classification of habitat types introduces further variability (Roper and Scarnecchia 1995). Among KNRD surveyors, a distinct difference in the way habitats with certain characteristics (e.g. velocity, channel shape, and surface turbulence) were consistently classified by different observers has been noted over the years. The tendencies were for some observers to classify a habitat as a run while other observers classified the same habitat as a pool. Observer variability in habitat typing may be decreased if the monitoring protocol is designed to capture the desired changes in habitat. Riley and Fausch (1995) were able to detect desired habitat changes in the three years following installation of log drop structures in Colorado streams. The objective of the enhancement was to increase pool habitat. They too used a transect based method to monitor physical habitat. However, transect spacing in their monitoring protocol varied from 1-5 m depending on the lengths of habitat units whereas our protocol was a standardized 5 m spacing. Their methodology was designed, in part, to monitor changes in pool volume, which was estimated by measuring depths at 1 m intervals in all identified pools. Due to the 5 m spacing, our monitoring occasionally missed constructed pools entirely; pools created by enhancement structures would fall in the 5 m area between transects.

Variability in habitat type is also associated with changes in streamflow (Sullivan et al. 1987; Hogan and Church 1989). In two small headwater streams, Herger et al. (1996) compared habitat measurements collected in July and August. Discharge declined from July to August and, based on the criteria they used for habitat classification, pool frequency increased with the decreased flows. Based on our observations, when flows are low, pool depths decrease making it more unlikely that a pool is classified as primary. Also, lower flows (decreased depths) may result in higher surface turbulence; sites were often classified as runs in high flow years and, due to higher turbulence, as riffles in low flow years. 2003 appeared to be a very low streamflow year. In Mineral Creek, average depths at all three restoration sites were lower than any other year (Table 41). At two of the sites, average depths were less than 30% of the pre-assessed depths. Also, no primary pools were identified in 2003 where a total of six were observed in pre-assessments of the three sites. Due to variability in habitat types with changing flows, Herger at al. (1996) recommended that comparing habitat estimates at different discharges be avoided.

Our current restoration monitoring appears to have the following shortcomings: 1) data analyses appear to rely too heavily on habitat classification which varies with observer and discharge 2) no control or reference reaches have been established as part of the monitoring protocol; therefore, effects from restoration treatments are difficult to distinguish from all other sources of variation, and 3) transect measurements (e.g. depths, widths) are not concentrated enough to detect changes resulting from enhancement structures.

Due to historic riparian harvest, streams in the lower Pend Oreille River sub-basin generally lack LWD. Most of the projects we have implemented focused on restoring the wood component and associated functions (e.g pool habitat, complexity). However, our monitoring does not appear to provide the information needed to evaluate these projects. We recommend changing our monitoring protocol to better implement and evaluate habitat enhancement projects. For physical habitat, we propose using Rosgen (1996) level III and level IV assessments to assist in selecting future enhancement sites and monitoring results. Habitat types will not be assessed so observer variability will be eliminated. Rather, surveyed cross-sectional and bed profile data will be used to compare pre and post implementation variables (e.g. residual pool volume, width to depth ratio). Residual pool depth and bankfull width measurements are independent of discharge therefore allowing comparisons of data regardless of flow. Stream channel assessments and stability analyses will be conducted on reference and impaired reaches to evaluate degree of geomorphic departure. Reference reach data is used to establish the "stable state" of a particular reach type and to generate dimensionless ratios for application in natural channel design. Fish populations will be monitored using standard snorkel techniques. A monitoring station will be established and snorkeled prior to implementing enhancement to establish pre-project density. Two control snorkeling stations will also be established: 1) a station adjacent to the project area to monitor population response to the enhancement and, 2) a station located outside of the project area to monitor natural variability. This monitoring protocol should help in our understanding of natural variability and the results should provide the information necessary to integrate adaptive management principles into future restoration plans.

LARGEMOUTH BASS HABITAT ENHANCEMENT MONITORING

DESCRIPTION OF STUDY AREA

The bass habitat enhancement study was located in zero flow areas of the reservoir (i.e. adjacent to and within sloughs). Four sloughs were used for the study:

1) Campbell slough adjacent to the Pend Oreille Wetlands Wildlife Mitigation Project, located on the east side of the Box Canyon Reservoir, at river km 99 (Figure 36).

2) No Name slough located directly across the reservoir from Campbell slough, on the west side of the reservoir, at river km 99.

3) Cee Cee Ah slough, located within the Kalispel Reservation on the east side of the reservoir, at river km 109.

4) Old Dike slough, contained within the Kalispel Reservation and located on the east side of the reservoir, at river km 107.

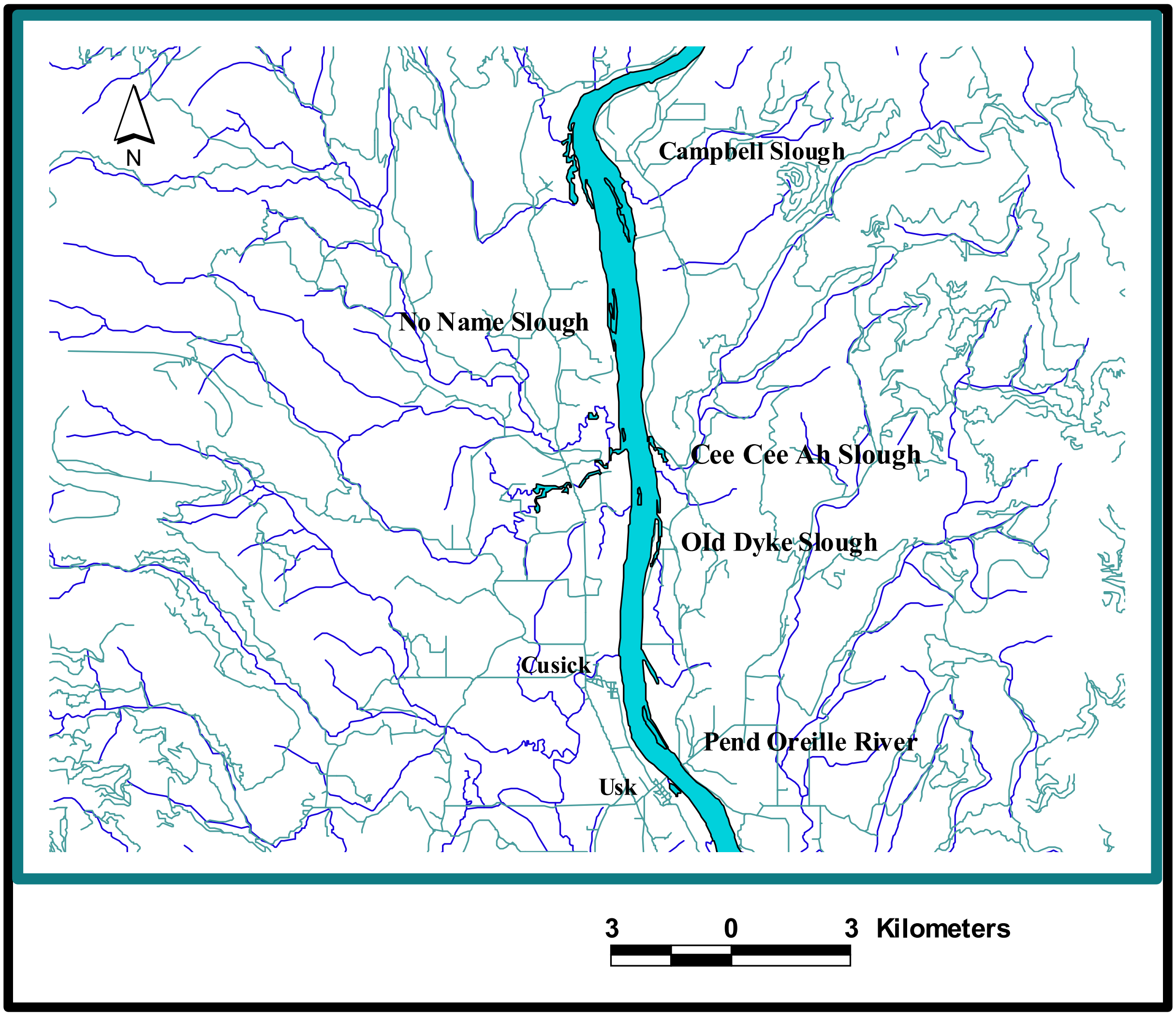

Figure 36. Location of the bass habitat enhancement sites.

METHODS

Selection of the sloughs used in the bass habitat study was based on the two types of sloughs available within the reservoir. The sloughs are either backwater stream mouths or dead end river backwater. Four sloughs were selected: one stream fed treatment slough, one stream fed control slough, one backwater treatment slough and one backwater control slough.

Two types of artificial structures were used in the treatment sloughs. The Berkley structures are 4-ft. cubes of plastic slats that provide cover in the interstitial spaces. The Pradco structures resemble palm trees and provide cover under the palms. The placement of each type was alternated between the two treatment sloughs (Berkley in the mouth transect in one slough and in the inland transect of the second slough).

Each slough was sampled prior to artificial habitat installation. Two 75 m sampling transects were established for each slough. Between the transects, a 75 m buffer was established to avoid data collection overlap. Each transect was then electrofished for a period of 300 seconds and all fish were collected. Bass total lengths and abundance were recorded; all other fish were recorded as total numbers by species.

In the spring and fall, each transect is electrofished annually. Relative abundance (CPUE) and species composition are calculated for each transect. Analysis will include whether the structures increase the abundance of juvenile largemouth bass.

RESULTS

From 1997 (pre-assessment) to fall 2002, largemouth bass relative abundance increased at every sampling site with the exception of Cee Cee Ah Slough #1 which was unchanged. Sampling of the largemouth bass enhancement sites did not occur in the fall of 1998, 2000, and 2003. Early sub-freezing temperatures iced the sloughs over in early November and the ice remained throughout the month. In Cee Cee Ah Slough #1, largemouth bass relative abundance was 2 in the fall of 1997 and again in the fall of 2002 (Figure 37). In Cee Cee Ah Slough #2, largemouth bass were only present in the catch in the fall of 1999 (n=2, Figure 38) and in 2002 (n=1).

In No Name Slough #1, largemouth bass relative abundance appeared to increase significantly in the fall of 1999 when 14 were collected (Figure 39). No largemouth bass were collected in the 1997 pre-assessment or the 1999 to 2003 spring post assessments. Three largemouth bass were collected at this site in the fall of 2002. No bass were present in the 1997 pre-assessment sample in No Name Slough #2 (Figure 40). Two bass were collected in the spring of 1998 and four bass were collected in the fall 1999 sample. No fish were collected in the 1999, 2000, 2001, or 2003 spring sampling periods and 6 largemouth bass were present in the 2001 and 2002 fall samples.

In Old Dyke #1, two bass were captured in the 1997 pre-assessment (Figure 41). Prior to fall of 2002, largemouth bass were collected in only three other sampling periods: one in the fall of 1999 and 3 in the fall of 2001. No largemouth bass were present in the catch in any of the spring sampling periods. However, in the 2002 fall sampling period 39 largemouth were captured in Old Dyke #1. In Old Dyke #2, largemouth bass were present in the catch in all sample periods except in the spring of 2001 (Figure 42). One bass was captured in the 1997 pre-assessment and three were captured in the fall of 2001. Twenty largemouth bass were captured in 2002; an increase of 333% over any other sampling period.

In Campbell Slough #1, largemouth bass have been present in the catches of all sampling periods. Largemouth bass relative abundance increased dramatically from pre-assessment (n=1) to fall 2002 (n=24)(Figure 43). Largemouth bass abundance in the spring of 1998 and 2001 was also relatively high with 19 and 17 bass captured, respectively. Largemouth bass relative abundance initially increased in Campbell Slough #2 (Figure 43). The 1997 pre-assessed abundance was 1. Large increases were observed in spring 1998 (n=19) and spring 1999 (n=18). Five largemouth bass were captured in fall 1999. Bass numbers declined in the fall of 1999 (n=5) and spring of 2000 (n=1). However in 2001 and 2002, fall largemouth bass relative abundance was relatively high at 30 and 23, respectively.

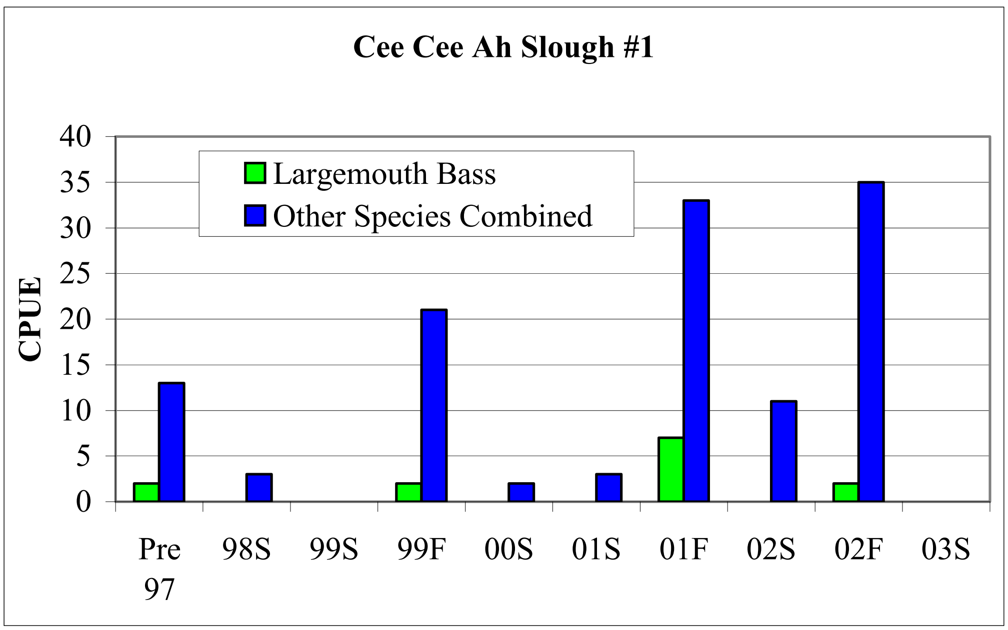

Figure 37. Largemouth bass and combined fish relative abundance for transects in Cee Cee Ah Slough #1.

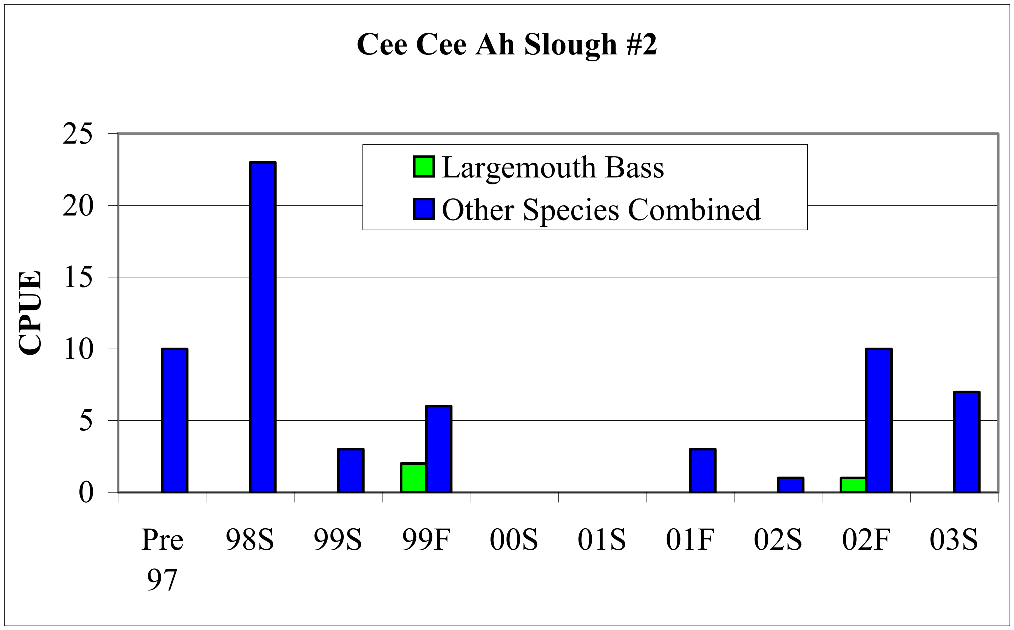

Figure 38. Largemouth bass and combined fish relative abundance for transects in Cee Cee Ah Slough #2.

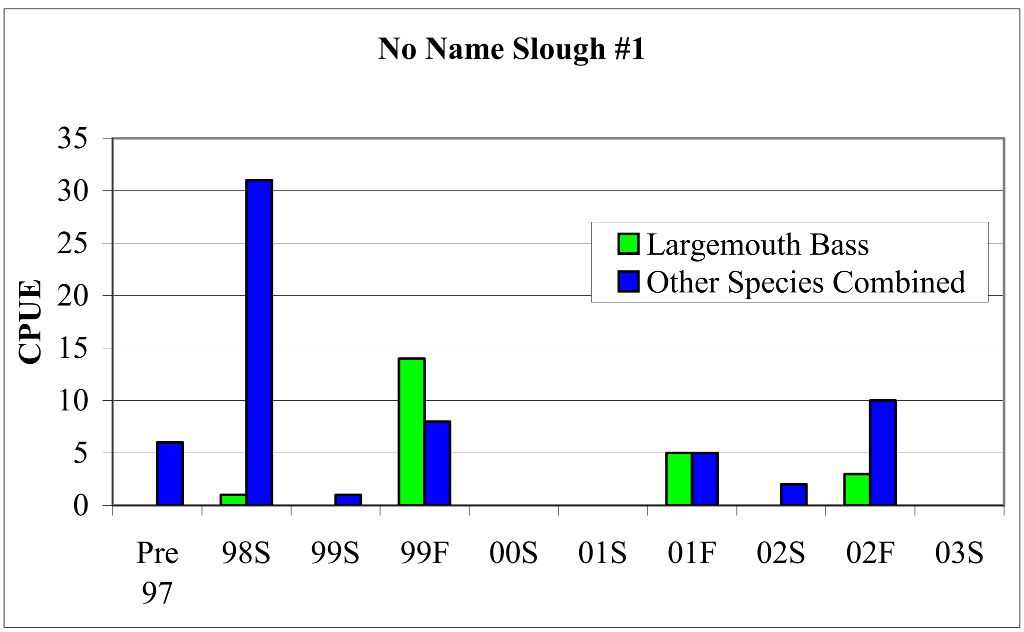

Figure 39. Largemouth bass and combined fish relative abundance for transects in No Name Slough #1.

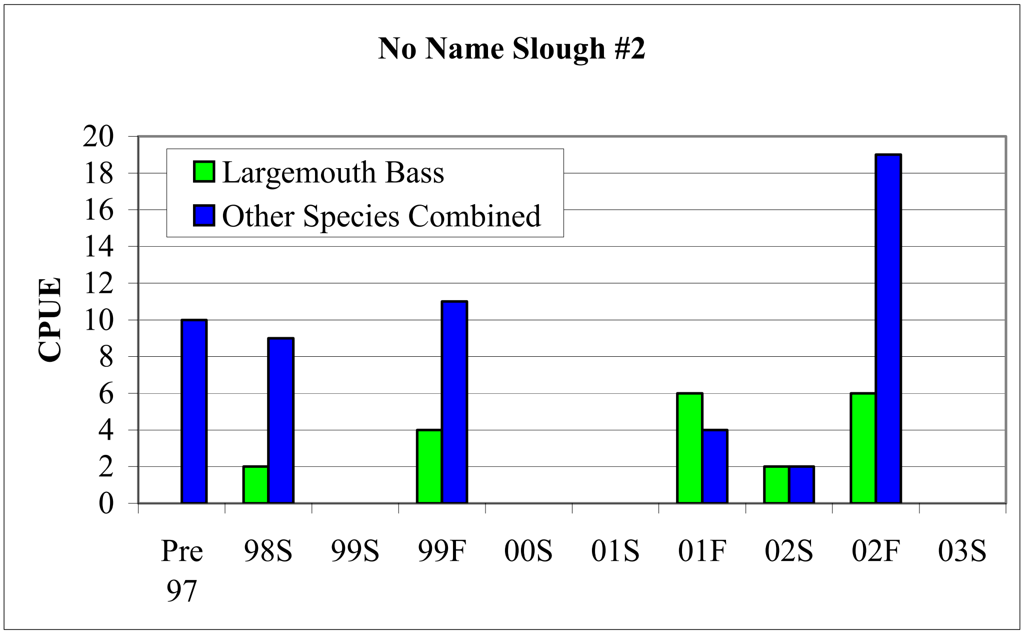

Figure 40. Largemouth bass and combined fish relative abundance for transects in No Name Slough #2.

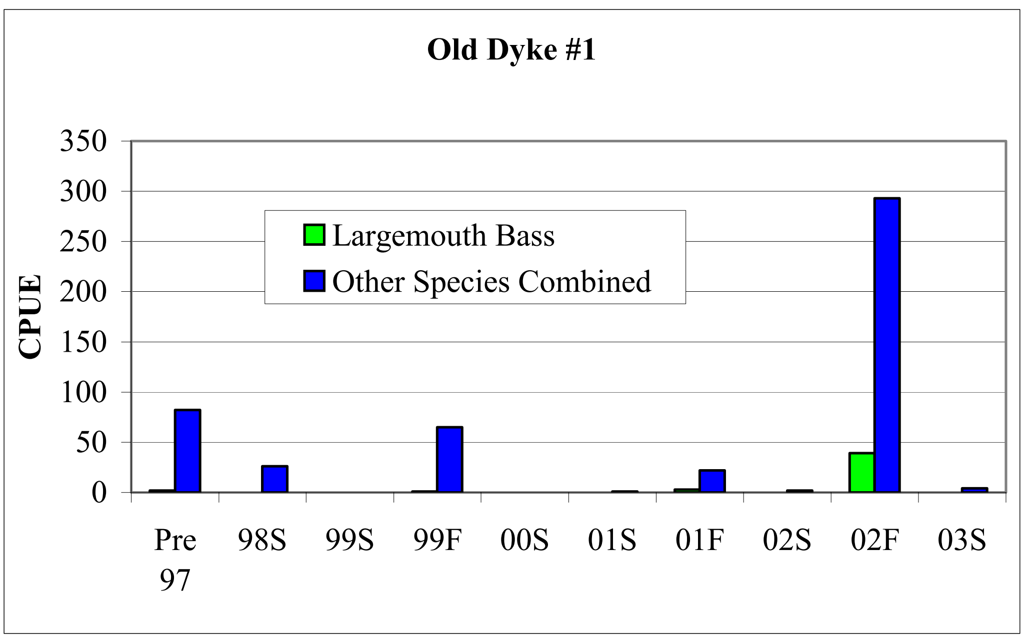

Figure 41. Largemouth bass and combined fish relative abundance for transects in Old Dyke Slough #1.

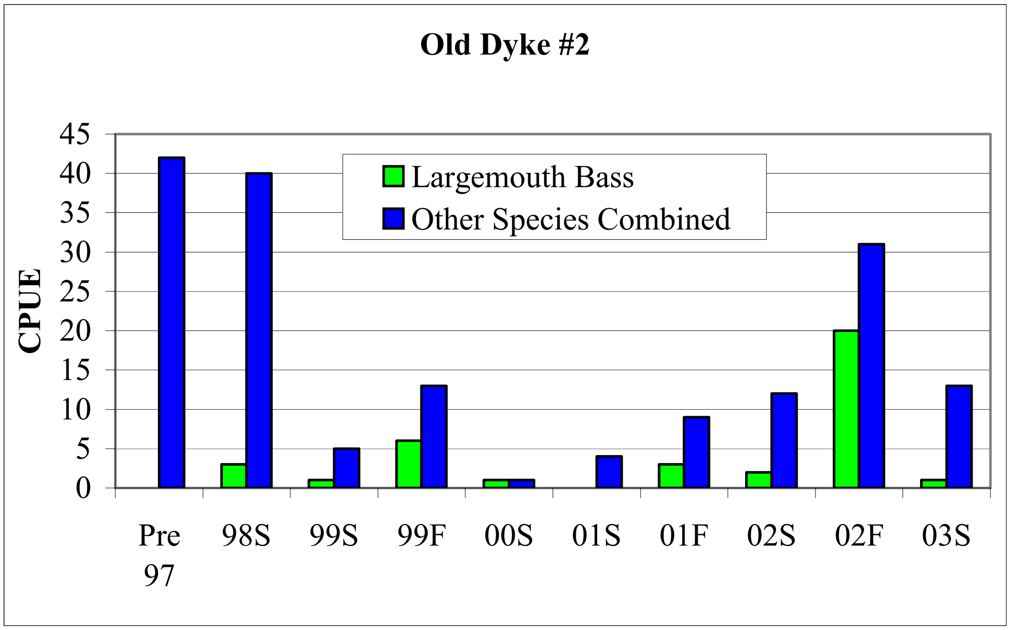

Figure 42. Largemouth bass and combined fish relative abundance for transects in Old Dyke Slough #2.

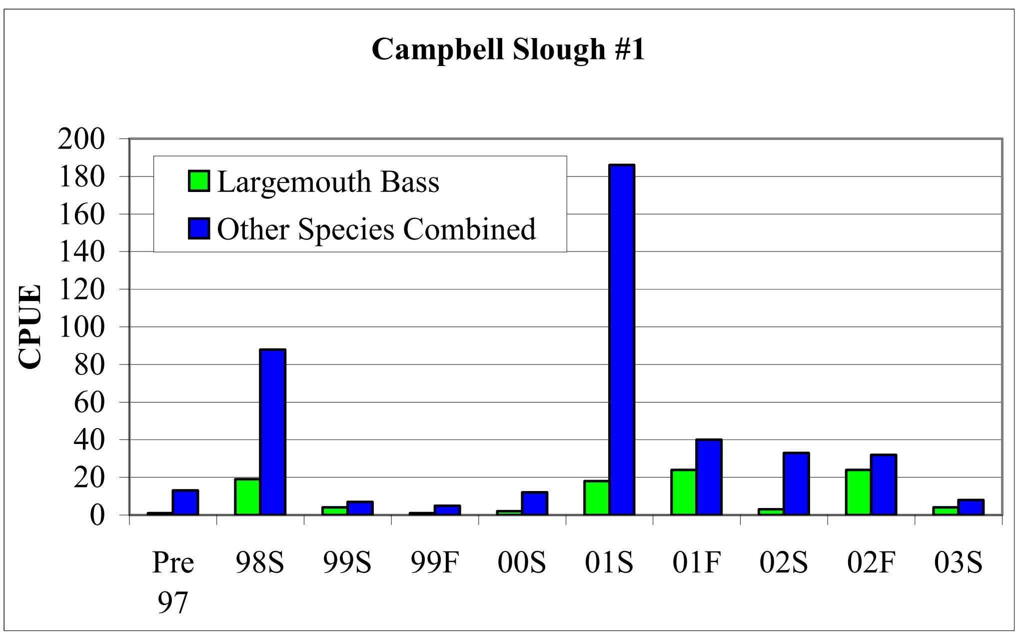

Figure 43. Largemouth bass and combined fish relative abundance for transects in Campbell Slough #1.

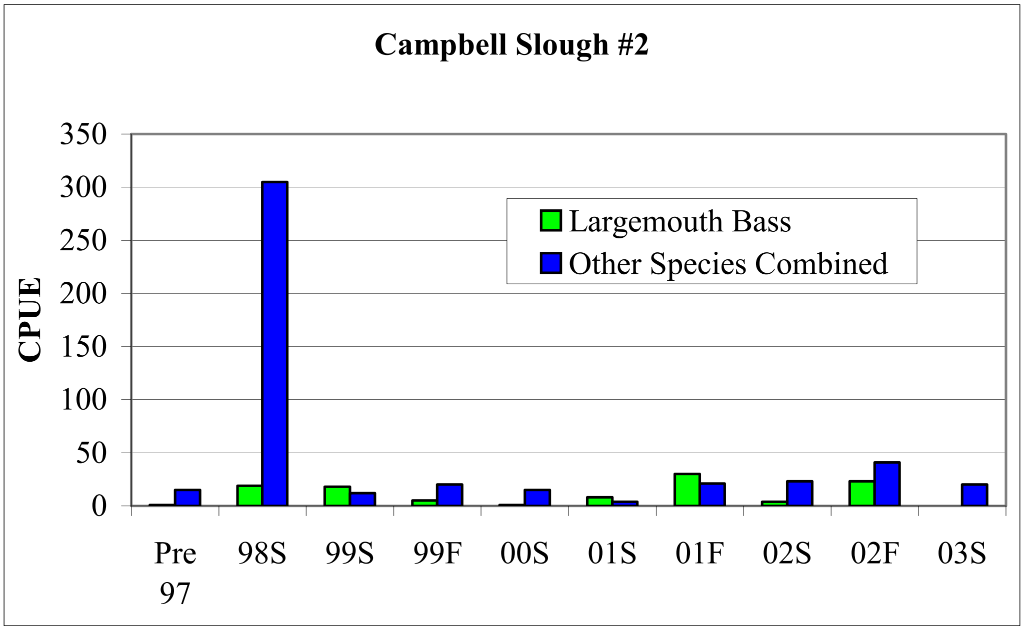

Figure 44. Largemouth bass and combined fish relative abundance for transects in Campbell Slough #2.

DISCUSSION

The mean size of largemouth bass was significantly different for fish captured in the fall and spring (*P*<0.0001). Juvenile largemouth bass are more likely to be present in the catch in the fall while larger adults are captured more frequently in the spring (Figure 45). The length frequency graph appears to have distinct modes for age 0+ and age 1+ largemouth bass. The means were 66 mm and 146 mm for age 0+ and age 1+ fish, respectively. Dampening of the length frequency modes occurred for fish older than 1+.

In the fall of 1997, before any bass structures had been placed (pre-assessment), no adult largemouth bass were captured in any of the sample sloughs. In 2002, seven adults were captured in the fall sampling period (Figure 46). A total of seven juvenile largemouth bass were captured in the pre-assessments of fall 1997. Juvenile numbers increased in successive fall sampling periods and a total of 115 age 0+ and 1+ largemouth bass were captured in 2002.

The percent of the catch has increased for all bass combined (Figure 47). Largemouth bass comprised 3.5% of the catch in the 1997 pre-assessment. Percent of catch was higher in all post assessment samples and ranged from 7.7% in the spring of 1998 to 44% in the spring of 1999.

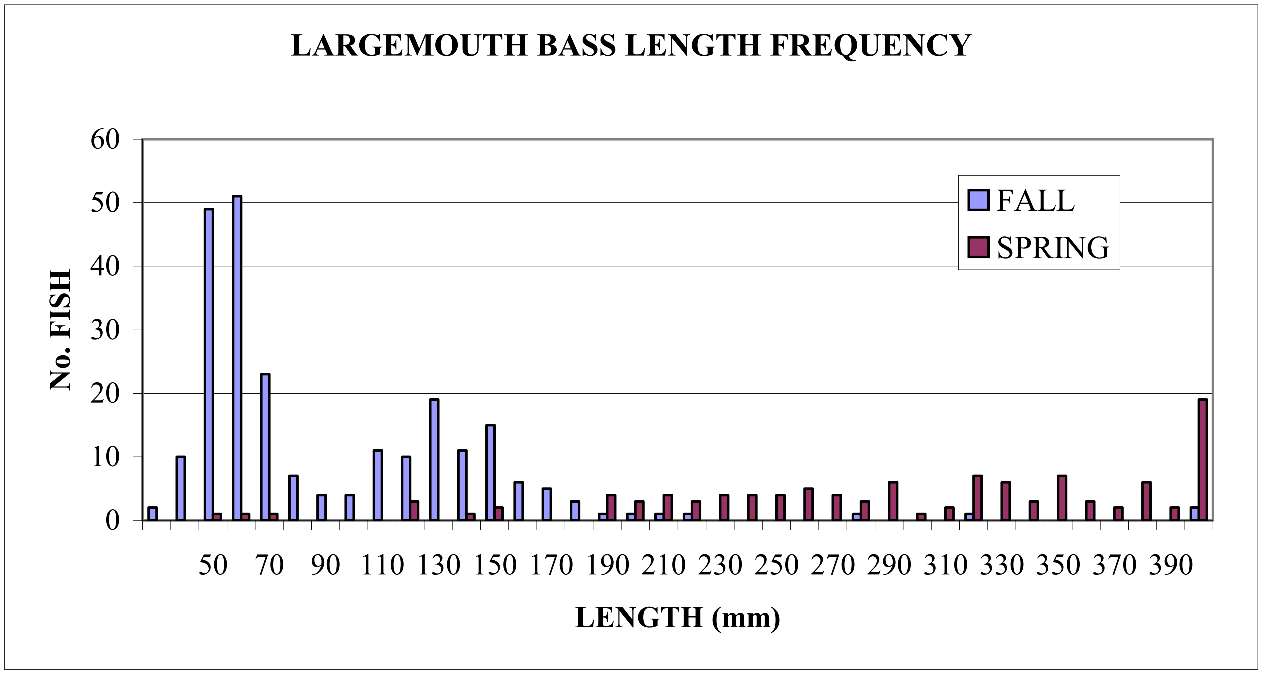

Figure 45. Largemouth bass length frequency for all stations sampled from 1997 to 2003.

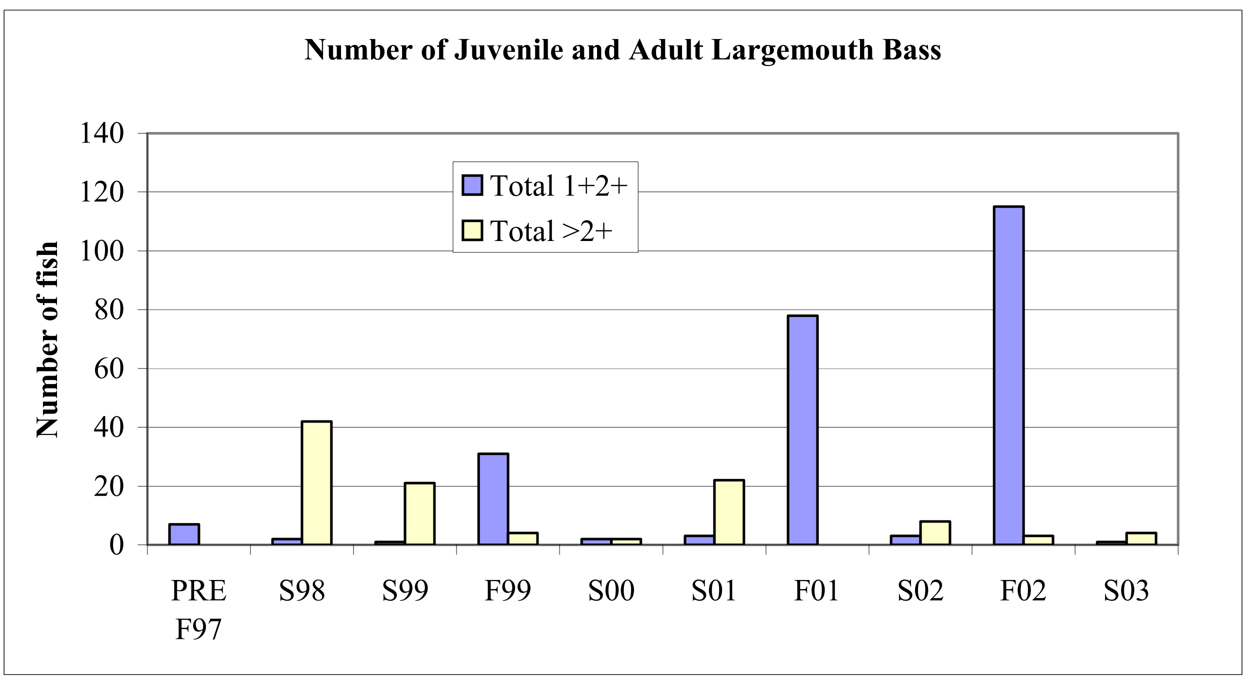

Figure 46. Numbers of juvenile and adult largemouth bass captured during spring and fall sampling periods from 1997 to 2001.

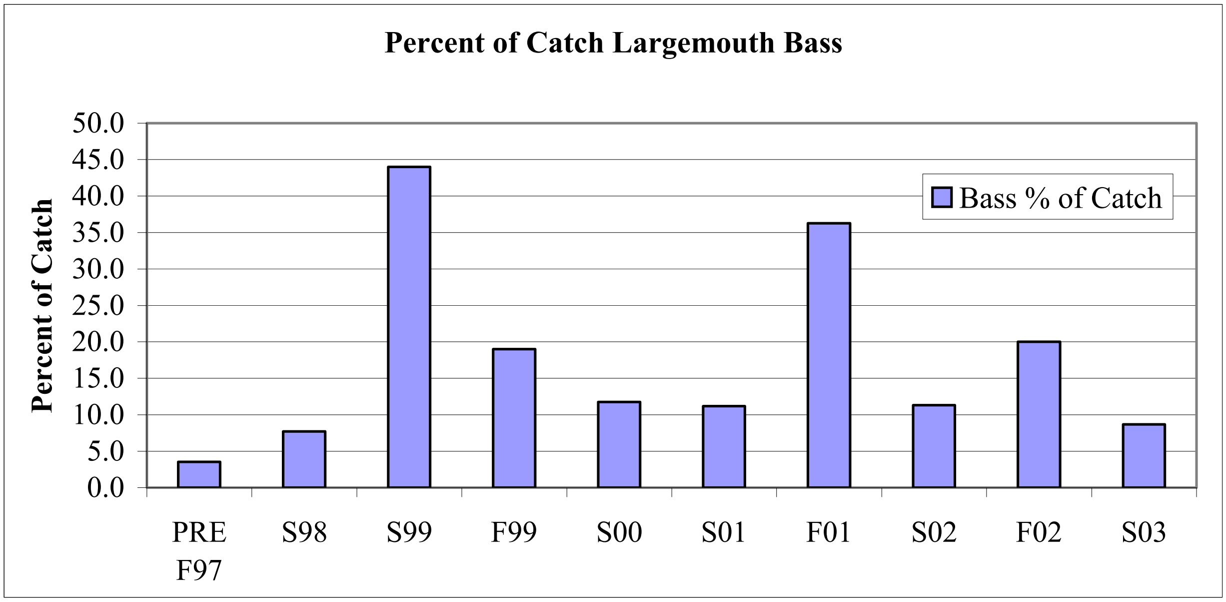

Figure 47. Annual percent of the catch of largemouth bass for all sampling transects.

Overall, largemouth bass CPUE and percent of catch have increased since bass habitat enhancement structures were implemented in 1997. However, distinct differences in seasonal utilization of the structures by juvenile and adult largemouth bass were apparent. 81% of the bass captured in the spring were adults while 97% of the bass captured in the fall were juveniles. The goal for this project is to provide overwinter cover to juvenile largemouth bass. Juvenile bass appear to have relatively low utilization of the structures in the spring. However, total juvenile relative abundance has increased from 7 in the fall of 1997 to 115 in the fall of 2001. In November, macrophytes in the sloughs and mainstem of the Pend Oreille River are likely providing significant cover for largemouth bass. In the spring however, macrophytes have decomposed and the artificial structures may then be the primary cover component. Adult largemouth bass may seek out the cover of the structures and displace the juvenile bass, which are vulnerable to predation. It is not known when the shift between juvenile and adult largemouth bass utilization of the structures takes place. However, given the increase in fall juvenile relative abundance, it appears that the enhancement structures may be resulting in increased overwinter survival for juvenile largemouth bass.

2003 NON-NATIVE FISH REMOVAL

DESCRIPTION OF STUDY AREA

Saucon Creek is located in the headwater portion of West Branch of LeClerc Creek. The removal was started just upstream from the confluence of Saucon (elevation 1103 m) and West Branch LeClerc creeks. The removal project was terminated 2.04 Km (1.2 miles) upstream at an elevation of 1280 m.

Mineral Creek is a headwater tributary to West Branch LeClerc Creek. The non-native fish removal project started approximately 350 m upstream from the confluence at an elevation of 1036 m. The removal project was terminated 3.7 Km (2.3 miles) upstream near an elevation of 1240 m. This is the second year of treatment on Mineral Creek. Only one pass was made during the 2003 treatment.

West Branch LeClerc Tributary 1 (an un-named tributary) is located just to the west of Saucon Creek. The removal started at an elevation of 1097 m and was terminated 1 Km (0.6 mile) upstream at an elevation of 1219 m.

METHODS

Non-native Fish Removal

Streams were electrofished using a battery operated Smith-Root LR-24 electrofishing backpack unit. To avoid imminent re-invasion by brook trout, electrofishing commenced at a point in the channel where fish passage was difficult if not impossible. The stream was partitioned into 100 m reaches using 1-cm mesh block nets at both ends of the reach to prevent immigration or emigration of fish before and during electrofishing. All passes were electrofished with relatively constant effort and care was taken to remove all possible stunned fish. In Saucon Creek three passes were made for each 100 m section. All fish captured in each pass were removed from the electrofished section. Captured cutthroat trout were released in the adjacent, downstream section (which had previously been electrofished). Captured brook trout were transported in a holding tank to another location and released. Electrofishing occurred upstream until brook trout were absent in the catch in three consecutive 100 m sections.

West Branch LeClerc Trib. #1 was electrofished using the same techniques described above. However, due to a change in weather and time constraints, a single pass was all that was completed.

In 2003 Mineral Creek was treated a second time. The second treatment used the same methods as Saucon Creek but only one pass was made.

RESULTS

Non-native Fish Removal

Twenty-one 100 m sections of Saucon Creek were electrofished to remove non-native fish. Brook trout were not captured in the last three sections. A total of 1031 brook trout were captured and relocated to the Pend Oreille River (Table 44). Westslope cutthroat trout were less abundant; 643 cutthroat trout were captured and returned to Saucon Creek.

Table 44. Numbers of fish captured during electrofishing removals in Saucon Creek.

Saucon Cr. Brook Trout Removal Cumulative Totals		
Pass No.	No. Brook Trout Captured	No. Cutthroat Trout Captured
1	738	494
2	201	97
3	92	52
TOTAL	1031	643

Thirty-one sections in Mineral Creek were electrofished using a single pass treatment. Mineral Creek was treated the previous year using a three-pass treatment. The single pass treatment was used this year to monitor the effectiveness of the previous treatment and remove additional brook trout. A total of 1232 brook trout were captured and relocated (Table 45).

Table 45. Number of fish captured during a single pass second treatment of Mineral Cr.

Mineral Cr. Brook Trout Removal		
Pass No.	No. Brook Trout Captured	No. Cutthroat Trout Captured
1	1232	739

Electrofishing removes in West Branch LeClerc Tributary 1 were limited to a single pass in 2003 due to time restraints and weather conditions. One Km of stream was treated. 260 brook trout were captured and relocated and 89 cutthroat trout were released back into the stream (Table 46).

Table 46. Number of fish captured during a single pass treatment in West Branch of LeClerc Trib. #1.

West Branch LeClerc Tributary 1 Cr. Brook Trout Removal Cumulative Total		
Pass No.	No. Brook Trout Captured	No. Cutthroat Trout Captured
1	260	89

DISCUSSION

The second phase of brook trout removal in Saucon Creek and West Branch LeClerc Creek Tributary 1 will occur in 2004 to determine effectiveness of the 2003 removal. Because they are more difficult to sight and capture, Age, 0^+ brook trout can have relatively low removal efficiencies (Thompson and Rahel, 1996). Saucon Creek and West Branch LeClerc Creek Tributary 1 channels contain an abundant volume of woody debris, making removal difficult with only one treatment. Therefore, Saucon Creek and West Branch LeClerc Creek Tributary 1 will be electrofished again, with one pass, in 2004.

In 2003 Mineral Creek received a second treatment to determine the effectiveness of the previous years treatment. In 2002 the ratio of brook trout to cutthroat trout in the treated section was 0.17. The second year of treatment yielded a ratio of 0.6. A total of 1232 brook trout were captured along with 739 cutthroat trout. Due to the large number of brook trout captured in the second treatment it was suspected that the barrier might be being breached. To answer this question approximately 300 brook trout were captured and marked downstream of the barrier and will be monitored for in the 2004 treatment. The removal appears to be having a positive affect on the native westslope cutthroat in Mineral Creek. A third treatment will be applied in 2004 to monitor the effectiveness of the two previous years treatment and to help make a decision if another treatment will be necessary in future years.

A similar project was just completed on Sheppard Creek in Montana. The treatment sections are almost exactly the same lengths and the numbers of brook trout captured per treatment are close to the same. The only really difference is the barrier used to prevent re-invasion. The Sheppard Creek project is using a large perched culvert built to be a barrier and the Mineral Creek project is using a natural barrier. The Sheppard Creek project is being considered a success by the USFS.

LITERATURE CITED

Anderson, H.W., M.D. Hoover, and K.G. Reinhart. 1976. Forest and water: effects if forest management on floods, sedimentation and water supply. USDA Forest Service Gen. Tech. Rep. PSW-18. 115 pp. 149,150.

Anderson, M. 1988. New directions for National Forest water quality planning. Forest watch. (March): 22-28.

Ashe, B.L., K.L. Lillengreen, J.J. Vella, L.O. Clark, S. Graves, M.R, Barber, G.J. Nenema, Jr., and A.T. Scholz. 1991. Assessment of the fishery improvement opportunities on the Pend Oreille River. Upper Columbia United Tribes Fisheries Center. BPA Annual report Contract No. DE-A179-88BP39339.

Barber, M.R., B.L. Renberg, J.J. Vella, A.T. Scholz, K.L. Woodward and S. Graves. 1990. Assessment of the fisheries improvement opportunities on the Pend Oreille River. Upper Columbia United Tribes Fisheries Center, Annual Report 1990.

Behnke, R.J. 1979. The native trouts of the genus *Salmo* of western North America. Report to U.S. Fish and Wildlife Service, Denver, Colorado.

Bennett, D.H. and M. Liter. 1991. Water quality, fish and wildlife characteristics of Box Canyon Reservoir, Washington. Department of Fish and Wildlife Resources College of Forestry, Wildlife and Range Sciences University of Idaho, Section 3: Fish Completion Report 1989-1990.

Beschta, R.L. 1979. Debris removal and its effects on sedimentation in an Oregon Coast Range stream. Northwest Science 53:71-77.

Bilby, R.E. 1984. Removal of woody debris may affect stream channel stability. Journal of Forestry 82:609-613.

Bilby, R.E., and J.W. Ward. 1991. Characteristics and function of large woody debris in streams draining old-growth, clear-cut, and second-growth forests in southwestern Washington. Canadian Journal of Fisheries and Aquatic Sciences 48:2499-2508.

Bisson, P.A., R.E. Bilby, M.D. Bryant, C.A. Dolloff, G.B. Grette, R.A. House, M.L. Murphy, K.V. Koski, and J.R. Sedell. 1987 Large woody debris in forested streams in the Pacific Northwest: past, present, and future. *In* Streamside Management: Forestry and Fishery Interactions, E.O. Salo and T.W. Cundy, eds. University of Washington Press, Seattle, WA. pp. 143-190.

DeStaso III, J., and F.J. Rahel. 1994. Influence of water temperature on interactions between juvenile cutthroat trout and brook trout in a laboratory stream. Transactions of the American Fisheries Society 123:289-297.

Eaglin, G.S.; Huybert, W.A. 1993. Effects of logging and roads on substrate and trout in streams of the Medicine Bow National Forest, Wyoming. North American Journal of Fisheries Management. 13:844-846.

Espinosa, A. 1988. Clearwater Stream Survey Methodology. Clearwater National Forest, Orofino, Idaho.

Fausch, K.D., and T.D. Northcote. 1992. Large woody debris and salmonid habitat in a small coastal British Columbia stream. Canadian Journal of Fisheries and Aquatic Science 49:682-693.

Fraley, J.J., and B.B. Shepard. 1989. Life history, ecology, and population status of migratory bull trout *(Salvelinus confluentus)* in the Flathead Lake and River ecosystem, Montana. Northwest Science 63: 133-143.

Frissell, C.A.; Liss, W.J. 1986. Classification of stream habitat and watershed systems in south coastal Oregon and an assessment of land use impacts. 1986 Progress Report prepared for the Oregon Department of Fish and Wildlife. Corvallis, OR: Oregon State University, Department of Fisheries and Wildlife, Oak Creek Laboratory of Biology. 51 p.

Goetz, F. 1989. Biology of the bull trout, *Salvelinus confluentus*, a literature review. U.S. Department of Agriculture, Forest Service, Willamette National Forest, Eugene, OR.

Goetz, F. 1991. Bull trout life history and habitat study. Master's Thesis. Oregon State University, Corvallis, OR.

Griffith, J.S. 1988. Review of competition between cutthroat trout and other salmonids. American Fisheries Society Symposium 4:134-140.

Griffith, J.S., and Smith R.W. 1993 Use of winter concealment cover by juvenile cutthroat and brown trout in the South Fork of the Snake River, Idaho. North American Journal of Fisheries Management 13:823-830.

Havis, R.N.; Alonso, C.V.; King, J.G.; Thurow, R.F. 1993. A mathematical model of salmonid spawning habitat. Water Resources Bulletin. 29(3): 435-444.

Heede, B.H. 1986. Designing for dynamic equilibrium in streams. Water Resources bulletin 22:351-357.

Hilderbrand, R.H., and J.L. Kershner. 2000. Conserving inland cutthroat trout in small streams: how much stream is enough? North American Journal of Fisheries Management 20:513-520.

Hillman, T. W. and W. S. Platts. 1993. Survey plan to detect the presence of bull trout. Don Chapman Consultants Inc. Intermountain Forest Industry Association.

Hunter, C.J. 1991. Better trout habitat: A guide to stream restoration and management. Island Press, Washington D. C.

Jakober, M.J., T.E. McMahon, R.F. Thurow, and C.G. Clancy. 1998. Role of stream ice on fall and winter movements and habitat use by bull trout and cutthroat trout in Montana headwater streams. Transactions of the American Fisheries Society 127:223-235.

Kalispel Natural Resource Department, Washington Department of Fish and Wildlife, and Spokane Tribe of Indians. 2001. Resident fish stock status above Chief Joseph and Grand Coulee dams Project #19970400 2000 Annual Report. DOE/BP-R00004619. Bonneville Power Administration. Portland, OR

Kalispel Natural Resource Department and Washington Department of Fish and Wildlife. 1997a. Kalispel Resident Fish Project Annual Report 1995. DOE/BP-37227-1. Bonneville Power Administration. Portland, OR.

Kalispel Natural Resource Department and Washington Department of Fish and Wildlife. 1997b. Kalispel Resident Fish Project Annual Report 1996. DOE/BP-37227-2. Bonneville Power Administration. Portland, OR.

Lacy, R.C. 1987. Loss of genetic diversity from managed populations: interacting effects of drift, mutation, immigration, selection, and population subdivision. Conservation Biology 1:143-158.

MacDonald, L.H., A.W. Smart and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. EPA/910/9-91-001. Developed for Region 10, US Environmental Protection Agency. College of Forest Resources/College of Ocean and Fishery Sciences, University of Washington, Seattle, Washington.

Markle, D.F. 1992. Evidence of bull trout x brook trout hybrids in Oregon. In: Howell, P.J. and D.V. Buchanan eds. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society: 58-67.

Meehan, W.R., ed. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. Bethesda, MD: American Fisheries Society. 751 pp.

Pearsons, T.N., H.W. Li, and G.A. Lamberti. 1992. Influence of complexity on resistance to flooding and resilence of stream fish assemblages. Transactions of the American Fisheries Society 121:427-436.

Platts, W.S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification with application to ecosystem classification. U.S. Forest Service. Billings, Montana.

Pratt, K.L. 1985. Pend Oreille trout and char life history study. Idaho Department of Fish and Game, Boise, ID.

Ralph, S.C., G.C. Poole, L.L. Conquest, and R.J. Naiman. 1994. Stream channel morphology and woody debris in logged and unlogged basins of western Washington. Canadian Journal of Fisheries and Aquatic Sciences 51:37-51.

Rieman, B.E. and J.D. McIntyre. 1993. Demographic and habitat requirments for conservation of bull trout. U.S. Forest Service General Technical Report INT-302.

Roper, B.B. and D.L. Scarnecchia. 1995. Observer variability in classifying habitat types in stream surveys. North American Journal of Fisheries Management 15:49-53.

Rosgen, D.L. 1994. A classification of natural rivers. Catena 22: 169-199.

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, CO.

Ruediger, R. and J. Ward. 1996. Abundance and function of large woody debris in central Sierra Nevada streams. FHR Currents, No. 20.

Saunders, H.R., R.J. Hobbs, and C.R. Margules. 1990. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5:18-32.

Sedell, J.R., G.H. Reeves, F.R. Hauer, J.A. Stanford, and C.P. Hawkins. 1990. Role of refugia in recovery from disturbances: modern fragmented and disconnected river systems. Environmental Management 14:711-724.

Scholz, A.T., K. O'Laughlin, D. Geist, D. Peone, J. Uehara, L. Fields, T. Kleist, I. Zozaya, T. Peone, and K. Teesatuskie. 1985. Compilation of information on salmon and steelhead total run size, catch, and hydropower related losses in the Upper Columbia River Basin, above Grand Coulee Dam. Upper Columbia United Tribes Fisheries Center Fisheries Technical Report No. 2.

Scatterlund, D.R., P.W. Adams. 1992. Wildland watershed management. John Wiley & Sons New York, New York.

Shaklee, J.B. and S.F. Young. 2000. A microsatellite DNA-based analysis of population structure of cutthroat trout *(Oncorhynchus clarki)* in the Pend Oreille Basin in Washington. Washington Department of Fish and Wildlife Completion Report.

Thompson, P.D., and F.J. Rahel. 1996. Evaluation of depletion-removal electrofishing of brook trout in small Rocky Mountain streams. North American Journal of Fisheries Management 16:332-339.